TOOL ENGINEERING

JIGS AND FIXTURES

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FIRST EDITION
FIFTH IMPRESSION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK AND LONDON
1922

PRINTED IN THE UNITED STATES OF AMERICA

THE MAPLE PRESS COMPANY, YORK, PA.

DEDICATED TO THE

MANUFACTURERS OF THE UNITED STATES

PREFACE

The aim and purpose of this book is to furnish information with respect to the science of tool engineering. Nothing has previously been published on the subject except in short articles dealing with specific examples of jigs and fixtures. Information of value regarding principles of design in connection with production tools is sadly lacking and mechanical literature contains only spasmodic efforts to remedy the deficiency.

In order to cover the subject properly three volumes were planned, each of these being complete in itself. This volume, which is the first, deals with the design of jigs and fixtures. It covers the important points connected with the design, shows the reasons why certain methods are better than others, takes up principles and their application to design and gives many graphic examples which illustrate the use of the principles involved. An endeavor has been made to simplify the subject matter as far as possible and to treat it in a practical common sense manner which can be easily understood by the designer. A careful study of the illustrations and descriptive matter will enable a progressive man to understand both the theory and practice necessary for this line of work.

The second volume takes up turret lathe and vertical boring mill tooling together with grinding fixtures. The third volume deals with punches, dies and gages.

For a number of years the machines and tools used for production have been undergoing a process of evolution and although the development work has progressed rapidly, much still remains to be done. Present manufacturing methods are of the highest order and tooling for high production is of interest to all the mechanical fraternity. There are however, comparatively few men in this country who really know the science in all its fundamentals and for this reason the tooling in many factories is probably not over 50% efficient.

A great many of those responsible for tooling are not well informed as to the fundamentals of design. Tools are worked out more or less by using ideas in vogue in the factory where the work is being done and the design is usually influenced by previous practice for work of the same character.

Progressive tool engineering requires first of all, a thorough knowledge of principles and the ability to specify the machining operations necessary on a given piece of work. With this as a basis, mechanical problems can be analyzed and the solution obtained by the application of known principles. For this reason our books take up the subject fundamentally and deal largely with principles although many examples of interesting fixtures are illustrated. *Mechanical principles are fixed* and do not change from year to year as designs often do; hence, the man whose knowledge of tools is firmly grounded on sound mechanical principles is independent, original and progressive, so that his designs are practical, economical and productive.

The superintendent, factory manager, foreman and tool engineer will find theory and practice combined in such a way that the principles on which the science is based will be readily understood. The reasons why one design is better than another are graphically shown in numerous examples, dealing with actual cases observed during the writers' long experience in handling production problems both in shop and drafting room. Problems are analyzed; causes of trouble shown; correct and incorrect methods illustrated; and much valuable data are given regarding designs and proportions of jigs, fixtures, turret lathe tools, punches, dies and gages.

It is our belief that the work will be appreciated by mechanical men throughout the country. We hope that the many practical examples will provide food for thought and eventually bring about a general revision and radical improvement in tooling methods.

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NEW YORK,
December, 1922.

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TOOL ENGINEERING
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CHAPTER I

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The science of tool engineering as it is now practiced dates back comparatively few years and very high production tooling is of even more recent date. A few years ago when production was small the majority of jigs were made as cheaply as possible, no great attention being paid to upkeep, because production was not sufficiently high to warrant it, except in the case of products which had been to some extent standardized, such as military rifles, army pistols, sewing machines, and similar work. The usual practice in the old days was to make a rough list of operations which was to be followed and then give a few free-hand sketches to the toolmaker to show him approximately how the tools were to be made, leaving many of the details to the man himself. When this man needed a pattern he went to the pattern maker and told him what he wanted, leaving the proportioning of the pattern to him. Then after the casting had been made the toolmaker "whittled" it out until a makeshift jig was evolved, which served its purpose in the production of so-called interchangeable parts.

The tool engineer of the present day must be up to date in the manufacturing field; must have a broad knowledge of machine tools; must understand the theory and practice of cutting tools, speeds, feeds and kindred subjects and should have practical shop training of such a nature that he *knows* from his own experience just how a given machine is handled and what the

requirements are for tools to be used on it. If he does not have this knowledge he will not be able to do the work required of him in the most efficient manner.

Listing of Operations.—In up-to-date tool engineering the first step in the process is the listing of the various operations necessary to machine each component part of the mechanism which is to be manufactured. In this listing of operations each step in the manufacture is considered carefully from various viewpoints, such as: Economy in handling; machine tools most suitable; tooling equipment available; production required; accuracy required; jigs and fixtures necessary; gages necessary, etc. In many cases, also, work may require heat treatment, local hardening, grinding after hardening, welding, riveting to some other unit, polishing, bluing or nickelplating. All of these matters must be considered in the listing of the operations. Hence it is evident that the tool engineer must not only be familiar with the processes of machining, hardening, gaging and grinding, but he must also understand the construction of the mechanism as a whole in order that he may decide on the necessity for machining this or that surface so that it will bear a distinct relation to some other hole or surface in order that the entire unit will function properly.

Points To Be Considered.—Let us assume that the blueprint of a certain part is turned over to the tool engineer, with the statement that the part drawing has been approved and is ready for tooling. The following points must then be taken into consideration in listing the operations:

1. *Production Required.*—This is an important consideration, which affects the method of handling to a considerable extent. If a comparatively small number of pieces is to be manufactured, the tools must be simple and cheap in order to keep the tool cost as low as possible. If a large number of pieces is to be manufactured, multiple fixtures and rapid clamping devices would be called for, in order to produce the work as rapidly as possible. In the latter case the cost of tools would be distributed over such a great number of pieces that the unit cost for tools would not be excessive.

2. *Material of Which the Work Is Made.*—It may be a casting, a forging or stamping, or it may be made from bar or flat stock. If a casting, it may need to be pickled, sandblasted and

snagged on a rough grinding wheel before machining. If it is a thin or irregular casting it should first be inspected both for quality and to see whether it has warped out of shape so that it cannot be machined to proper dimensions. If a forging it may require heat treatment before or during machining or it may be hardened and afterward ground so that necessary allowances must be made during the machining to provide sufficient stock for grinding. If made from round stock it may be found best to machine it from the bar on a screw machine, or perhaps its length and general shape may make handling it more profit-

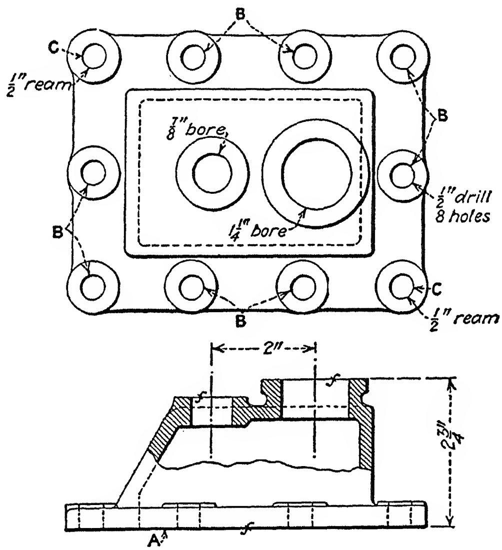


Fig. 1. Example Showing the Establishment of Working Surfaces To Be Used in Locating the Work During Machining

able on a manufacturing lathe after cutting it into lengths on a cold saw or a cutting-off machine. It is evident from the foregoing that the material of which the part is made is an important factor in the machining.

3. Surfaces To Be Machined.—In considering the various holes to be drilled, bored or reamed and the various surfaces to be machined, it is important first to decide whether the various holes can be drilled in one jig, or several jigs will be required; next, whether several milled surfaces can be machined

in one setting or it will be more economical to make several operations. It is also necessary to decide whether any other operations that may be necessary can be handled to best advantage in combination, or by several operations. It is not good practice to drill small holes and large ones in the same jig, unless drilling machines can be so arranged as to obtain correct spindle speeds for the different sizes of drills required. In special cases it may be found profitable to do something of this kind in order to avoid a resetting of the work and the cost of an extra jig.

4. *Accuracy Required.*—In any mechanism there are certain fundamental principles affecting the successful operation of the device. In order that it may function properly as a unit the various components which make it up as a whole must fit each other within certain limits of accuracy. These limits are usually specified on the drawings of each part and the tool engineer must keep them in mind when listing the operations as well as when designing the limit gages used in the production of the parts.

The accuracy with which various machine tools will work must be taken into consideration and if their accuracy is not sufficient to produce the results required, a final fitting or grinding operation may be necessary. So it is apparent that the accuracy required is a factor of importance in listing operations.

5. *Selection of Working Points.*—In order to obtain the best results in production it is advisable to select working points which can be used for location in all of the operations on the work. It is difficult to give a hard and fast rule for determining which points are the best to work from, due to the fact that different cases require different treatment and various pieces of work are of such widely different design that no fixed rule can be given to apply to all instances. A very good thought in connection with the establishment of locating points is first to obtain a flat surface and next machine two or more holes perpendicular thereto if the nature of the piece will permit it. In a case of this kind it is possible to work from the finished surface for all the subsequent operations, locating by means of pins in the drilled or reamed holes, and in this manner making certain that correct relations are kept for all the operations with the points established as working points. Sometimes it may be necessary to vary this procedure on account of the shape of the work, but the matter of establishing the working points must always

be considered very early in the listing of operations. A very good example which shows the establishment of working points is shown in Fig. 1, in which the flange A is first milled to give a surface to work from and in the next operation the flange holes B are drilled and two holes C reamed to give the other locations so that the work can be carried through its various operations by using these points from which to locate.

6. *Provision for Chucking.*—In the handling of work on the turret lathe it is frequently necessary to provide means for clamping or holding the work during the first operation. There are many cases where the shape of the work is such that it can be held in a chuck without difficulty, but in other instances it may be found necessary to provide the work with lugs in order to hold it properly. A case of this kind will be noted in the hub, illustrated in Fig. 2. In this case it was decided to machine the surfaces marked f in the same setting, and obviously it would be difficult to hold by means of the tapered portion A. By the addition of three lugs B the work can be readily held by the chuck jaws C, as indicated in the illustration. When lugs of this kind are added to a casting they may be removed by a subsequent operation or they may be left as they are, provided they do not interfere with the appearance or utility of the finished product.

7. *Concentricity of Cylindrical Surfaces.*—In the listing of operations the importance of concentricity of the cylindrical surfaces which must be in alignment should be carefully considered, as any variation from the truth will cause the mechanism when completed to cramp and not run smoothly. It is advisable wherever possible to machine concentric cylindrical surfaces in the same setting, but as this is not always practical, particular attention must be paid to the method of holding, when several operations are used, in order that the work may be true when completed. A very good example of a piece of work of this character is shown in Fig. 3. In this case the bearing seats A and B must be concentric to each other, and yet it is apparent that the two surfaces cannot be machined in the same setting of the work. For this reason the greatest care must be exercised in designing the tool equipment so that the first bearing seat B will be used as a location from which to produce the second bearing seat A. Many other examples could be given of

work of this character, but the instance given is a representative one which will serve to illustrate the points involved.

5. *Machines Required and Available.*—In the selection of machines for the work in process it is necessary that the tool engineer should be familiar with the various types of machine tools most suited to the work. In listing operations for an old plant having a considerable assortment of machine tools from which

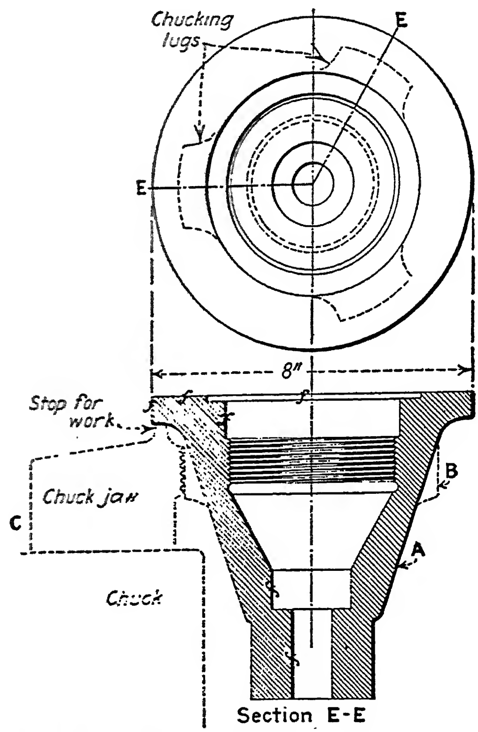


Fig. 2. Addition of Chucking Lugs to Assist in Machining

to choose the tool engineer must have a list of these machines together with necessary data on their capacities and their working ranges. It must always be borne in mind, however, that the selection of a machine for high production should not be dependent entirely upon the machine tools which are in stock, and it may be more profitable to purchase new equipment rather than to use old equipment which is out of date and does not give maximum efficiency.

Buy Tools as Needed.—It is obvious that when listing operations for a new plant the machine tools can be selected as they are needed and can be bought as the occasion demands. In cases of this kind the tool engineer must be open-minded and must make his selection after having looked into the possibilities of the newer types of machines on the market.

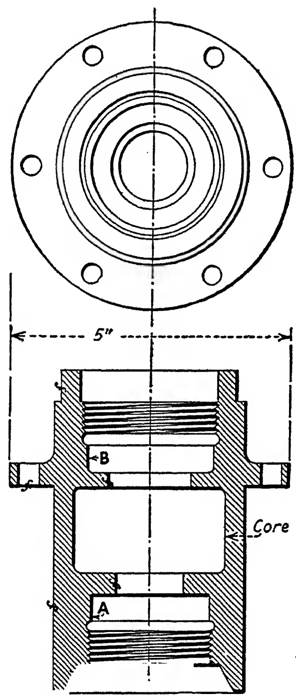


Fig. 3. Concentricity Between Seats *A* and *B* Very Essential

Plant Layout.—In handling production work the layout of the plant has an important bearing on the speed with which the work can be routed through the factory. In the case of a new factory it is evident that a plant layout must be made which will show the position of all machine tools suitably placed, so that there will be room for the piling up of raw material and the finished product. The plant engineer who understands his business takes all these matters into consideration.

Some of the points which come up in the placing of machines

are illustrated in Fig. 4. In this case the drilling machines shown at *A* and *B* and the tapping machine shown at *C* have

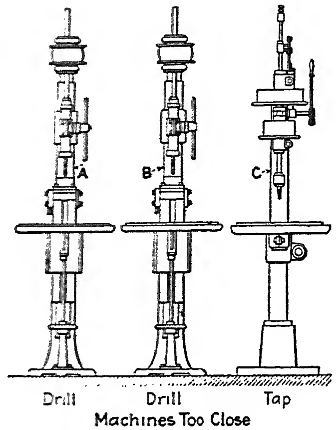


Fig. 4. Example Showing Drilling Machines Set Too Close Together

been placed so close together that it would be difficult to find space for the work both before and after machining. A much better arrangement is shown at *D, E* and *F* in Fig. 5. It will

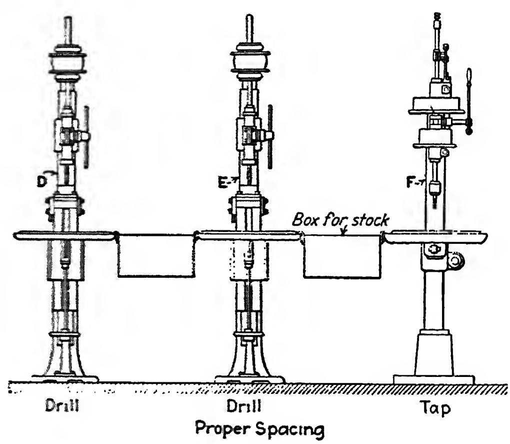


Fig. 5. Drilling Machines Properly Spaced

be noted that these machines are more widely separated so that boxes can be placed between them for collecting the material as fast as it has been drilled or tapped. These boxes can be so

made that they will hang on the edge of the drill-press table, or they can be resting on the floor. They can be readily removed and replaced if desired.

Another example of the placing of machines is given in Fig. 6. The upper view at *A*, *B* and *C* shows an arrangement of screw machines which is very bad because it does not make suitable allowance either for the stock in the machines or for the piling of the stock on the floor alongside of the machines. Referring

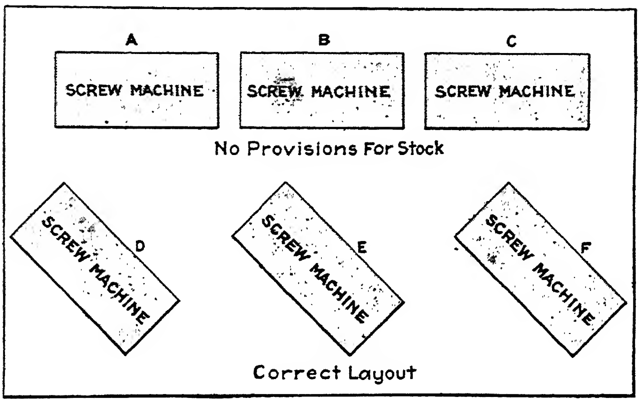


Fig. 6. Improper and Proper Spacing of Screw Machines

to the lower portion of the illustration *D*, *E* and *F* show a much better arrangement, with plenty of room for finished and unfinished stock.

Tool Equipment Required.—When the tool engineer has decided on his sequence of operations it will then be necessary for him to decide what tools will be used in the production and also what gages will be necessary to hold the work within the required limits of accuracy. It is customary for the engineer to talk over each piece of work in a conference with his chief draftsman and possibly some others who are intimately connected with the production work in the shop. At this conference it is decided just what varieties of tools would be best for the various operations, and in all probability rough sketches are made to indicate in a general way the kinds of tools needed.

A decision would be reached regarding the use of single or multiple fixtures, and the machine tools to be used would also

be selected. As the shop superintendent is likely to be one of the men in the conference he would undoubtedly have certain preferences in regard to the tools to use for certain operations. After a decision has been reached as to just how each piece is to be handled the list of operations should be typed and turned over to the chief draftsman, who can then start on the design of the necessary tools.

Effect of Design on the Cost of Machining.—It frequently happens that in working out the tools for the various operations it is found that the shape of the work makes it difficult to

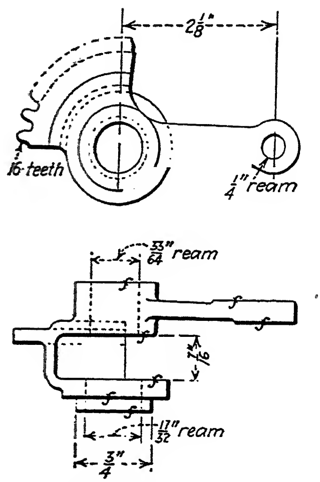


Fig. 7. A Difficult Casting to Machine

machine, and in many cases it may be found advisable to modify or change the shape of the work slightly in order to assist in the handling and cheapen the cost of manufacture.

A very excellent example of such a condition is shown in Fig. 7, which shows a small bronze casting correctly designed so far so its part function is concerned. When the design of tools was started it was found to be a very difficult proposition to obtain tools that would give good results. The original routing of operations was as follows: (1) Straddle-mill inside bosses and one end; (2) straddle-mill small arm; (3) drill and ream 33/64-in. hole through both ends and $\frac{1}{4}$-in. hole to size; (4) turn $\frac{3}{4}$-in. end; (5) cut teeth; (6) ream 19/32-in. hole.

The first operation was difficult to hold, due to the two diameters that were to be located in V-blocks. The variation in the casting would throw out the work, causing the subsequent operations to be out of line.

The second operation was to be held in the same manner, using the milled slot for location, and the small arm required a clamp which was very weak, due to the thickness of the portion it was to clamp.

The third operation could not be finished in such a way as to be certain that the holes would be in the correct relation to the

DOWD ENGINEERING CO.
TOOL AND OPERATION SHEET

CUSTOMER BLANK REGISTER CO.
ADDRESS New York

PIECE No. A13139
NAME Segment Yoke
No. PIECES PER UNIT One
MATERIAL Bronze Casting

1/1

Oper. No.	Description of Operation and Method of Holding Work	Type of Mach.	Tools, Gages and Fixtures	Tool Number	Dowd Order No.	Hr. Prod.	No. Mach. Reqd.
1	Drill and ream large holes, face and turn hub on large end, cut off chucking stem, allowing stock for profiling.	Screw mach.	Collet jaws, tool block, facing tools, cut-off tool, drills (std.)	9191 9192 9193 9194	1416 1417 1418 1419	60	1
2	Profile small end to length and one side of small arm.	Profiler	Profiling fixture, Profile cutter (std.)	9195	1420	60	1
3	Profile other side of small arm..	Profiler	Profiling fixture .. Profile cutter (std.)	9196	1421	100	1
4	Drill and ream hole in arm.. ...	Drill press	Drill jig....... . . . Drill (std.)	9197	1422	75	1
5	Cut teeth..................,	Gear cutter	Special arbor...... Hob (std.)	9198	1423	60	1
6	Mill inside bosses..............	Plain miller	Milling fixture..... Cutter (std.)	9199	1424	75	1

Fig. 8. Revised Routing for the Piece Shown in Fig. 7

milled faces. An operation of this kind is also very difficult to line up to assure a hole which will be true with the milled surfaces.

The fourth operation required a special arbor with an undercut in order to allow the tool to face the end.

The fifth operation used a special hob which finished the outside diameter of the teeth as well as cut them.

The sixth operation was very hard to get in line with the small hole and the clamping was very difficult.

As the tools had been planned it was noted that considerable improvement could be made if the operations were revised, and after careful study the routing was changed as shown in Fig. 8.

For the first operation a chucking stem was provided for the work, as shown in Fig. 9, so that by gripping the work in the chuck it was possible to drill, bore and ream the holes through

the hub and to face and turn the end at *B* without any great difficulty, and then before the work was taken out of the chuck the chucking stem was cut off with the parting tool *C*, leaving the work clean and accurate and at the same time providing an excellent location for subsequent operations. It will be noted that a "tie-piece" *A* was cast in the work in order to prevent too much distortion and at the same time hold it together during the first machining operation. It is rather hard to appreciate the delicacy of this piece without seeing it but its construction

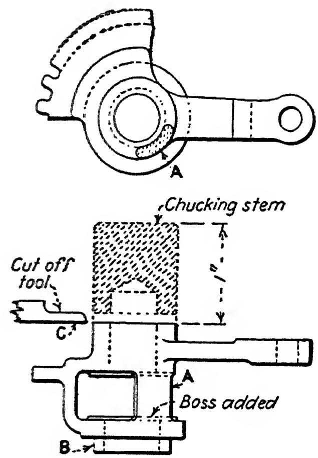


Fig. 9. Casting Revised to Assist in Machining

and lightness made it extremely difficult to machine without distortion.

The second operation was the profiling of the small end of hub to the correct length and surfacing one side of the arm. This work was done on a profiling machine, using a set block for the variation in the height of the cuts. The hole in the hub was used to locate from, making it certain that the work when finished would be absolutely true with the hole.

The third operation, which was that of profiling the other side of the small arm, was very simple and the fixture was arranged in such a way as to use the center hole from which to locate. A suitable set block was provided.

The fourth operation was that of drilling and reaming the hole in the arm. By using the center hole to locate from and

the finished surface of the arm to "bank" on it was very easy to design a jig for this operation which gave excellent results.

The sixth operation was that of milling the inside bosses and cutting out the tie piece. The work was located on studs in vise jaws. These jaws were provided with stop pins which prevented the jaws from crushing or distorting the work while the milling operation was taking place. It was found that the work did not spring over 0.0005 in. when the tie piece was cut out.

A great deal of thought was put on this particular piece as it was an extremely delicate one and difficult to machine. With the operations as originally laid out the tools would have been very costly and there would have been great difficulty in holding the work within the required accuracy. As the operations were finally revised the tools were simple and comparatively cheap and the work was held to a close degree of accuracy without difficulty.

Another Example.—A very excellent example of a change in design which resulted in a great saving in manufacture is shown in Fig. 10. This may be considered an exceptional example, in comparing the cost of the production of piece *A* as shown above and *B* as shown below. The work is a yoke connection which was originally made from a forging bulldozed from a machine steel rod. The finished piece was about 50 in. long. As originally made, the machining necessary to complete the unit was as follows: (1) Straddle-mill bosses; (2) drill and ream holes. Both the drilling and milling operations were very awkward, due to the length of the piece. This method was followed for some time until it was thought by tool engineers that considerable improvement could be made.

After some consideration the unit was made in two pieces as shown at *B* and *C*. The yoke end was blanked in one operation on a punch press with the holes pierced to the finished diameter. The work was then formed as shown, thus completing the yoke. The next operation consisted of welding the yoke to a rod of machine steel cut to the required length. This operation was rapidly done at a smaller cost, and the only remaining work needed to finish the piece was to dress off the welded section.

The comparative labor costs of the two methods of manufacture showed a saving of 30 per cent in actual labor in the latter method. Taking the cost into consideration the new method

does away with the milling cutters, drills and reamers, while the cost of punch-press dies just about offsets the forging dies originally used, so far as upkeep is concerned.

Threaded Work.—Very often when designing a piece of work which is to be threaded the designer does not take into consideration the cutting of the thread. In manufacturing work the majority of threads is cut by means of dies, and in order to have the dies work properly they should have a *lead* of at least

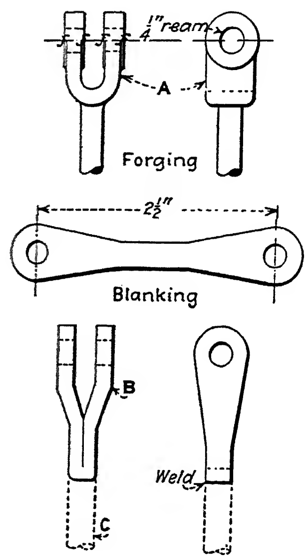


Fig. 10. Original and Revised Design of Yoke. Revised Design Resulted in Saving in Manufacture

two threads. That is to say, the first two threads should be chamfered to allow the die to run on to the work. Now it is evident that after two threads in the die are cut away like this it would be impossible for it to cut a full thread up to a shoulder. For this reason it is customary to show a relief of some sort in the thread if necessary to cut it close to a shoulder.

A very good example of a difficult piece of threaded work is shown at *A* in Fig. 11. This was an aluminum casting, the drawing of which called for a full thread directly up to the shoulder *B*. It was a production job and it was found to be practically impossible to cut the thread right up to the shoulder

as shown. A concession was finally made by the customer to permit the thread to stop one thread away from the shoulder and a groove was made at the point *C* to allow the die to run out. A little forethought on the part of the designer would have shown him the difficulty of cutting the thread up to the shoulder as shown and he should have made suitable provision on his drawing to take care of this matter.

Chucking Stem on a Gear Blank.—In making up spur gear blanks such as that shown at *A* in Fig. 12 it may be necessary

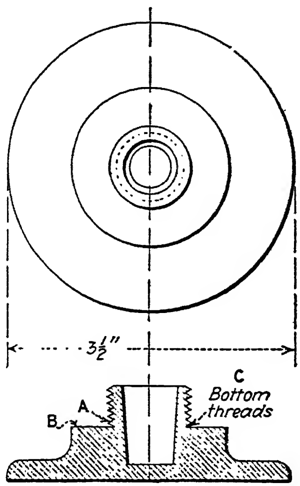


Fig. 11. A Difficult Piece of Threaded Work, Changed to Assist in Production

to make several settings of the work in order to machine it properly. If, however, a chucking stem is added as shown at *B* in the illustration the work can be held by means of the chucking stem in the chuck jaws *C* in such a way that all of the machining can be done in one operation. After the piece has been completely machined the parting tool *D* can be run in to cut off the blank as indicated in the illustration. An arrangement of this kind is very common and the same idea can be applied to many other cases of similar work.

Drilled Holes Close to a Shoulder.—When drilled holes are called for in a piece of work it is not only necessary to provide clearance for the drill but also, if the work is to be produced in quantities, sufficient clearance should be provided for the

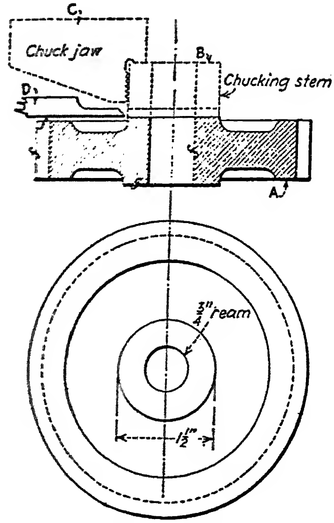


Fig. 12. Chucking Stem Added to Gear Blank

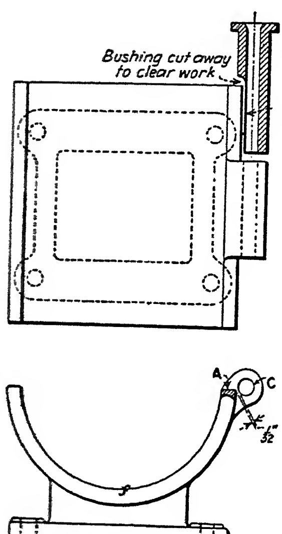


Fig. 13. Insufficient Clearance Allowed for Drill Bushing

drill bushing. An example of this kind is shown in Fig. 13, in which it will be noted that the hinge hole *C* is very close to the shoulder *B*. The drawing was marked "grind to suit" at point *A*. Evidently the intention was to grind away the casting slightly in order to allow clearance enough for the drill. As a matter of fact, when the jig was built the bushing was cut away as shown at *B*, but even when this was done the variation in the casting was so great that a proper location for the hole could not be obtained.

The obvious remedy for a design of this kind is to cut away the interfering shoulder far enough so that there will be plenty of clearance for the bushing. Cases of this kind are more or less frequent in general manufacture and it is often necessary to make slight changes in the design in order to drill the work correctly.

CHAPTER II

FUNDAMENTAL POINTS IN DRILL JIG DESIGN

Value of Analysis—Location of Rough and Finished Work—Correct and Incorrect Location and Clamping—Clearance for Work and Chips—Provision for Wear on Locating Surfaces—Setting Up and Removing Work—Types of Jigs

There are a number of elementary points which need to be considered in the design of drill jigs. The progressive designer considers these points almost unconsciously when he starts to design a jig. The beginner, however, and the man who has had only a small amount of experience in jig design must continually think of the things which he must look out for in his design. In taking up these various points they will be considered in elementary and graphical forms in order to make the *principles* clear and readily understandable. After the tool designer obtains a clear knowledge of the fundamentals which underlie the design of jigs and fixtures he will be able to analyze things for himself and he will know absolutely whether or not the principles on which he is working are correct.

Value of Analysis.—Let us digress for a moment to take up the matter of analyzing a problem before attempting to solve it. Every piece of work which is to be tooled must be very carefully looked over before any tooling is started, in order that a clear understanding of its functions and the importance of the various surfaces may be understood. In analyzing the processes considerable thought must be given to the machine tools which are to be used in the manufacture. If the work has been laid out by the tool engineer, there will be a list of operations which the tool designer can consult so that he will know just what machine tools are to be used for each operation. A complete analysis of the tool problems connected with the work should embrace also the types of jigs and fixtures most suitable, and

should consider the location of the fins, ribs or drafts, as well as any irregularities, in order that location points may be selected which will not be subject to variations caused by rough grinding, filing and chipping. It is always advisable for the tool designer to make such a thorough study of the piece of work which he is about to tool that he can carry it in his mind without having to question the relations of various portions to each other. After this analysis has been made he should be ready to start his first jig or fixture.

Points To Be Considered.—When designing a jig the follow- points must always be considered: the method of locating the work so that it will be machined in a uniform manner; the clearance between the jig body and the work; suitable provision for cleaning; chip clearance; accessibility in setting up and removing the work; distortion in clamping, etc. Various points in connection with these matters will be discussed in detail.

In locating a piece of work in a jig when no other operation has been performed on it previously, the greatest care must be taken to select such points for locating that inequalities in the casting or forging will not cause the work to be thrown out of line in such a way that subsequent operations will not give accurate results. The work may be a rough casting or forging and while the forging may be smoother and more accurate than the casting there is always the matter of draft to be considered. It is advisable wherever possible for the tool designer to obtain a sample casting or forging from which to work. Not only does this make the tool problem more simple, but at the same time it enables him to note where irregularities are likely to be found on the work and to guard against so placing a locating point that it will come in contact with some irregular surface. In a forging, if it happens to be a complicated one, there may be an excessive quantity of metal on certain parts, on account of forging conditions. Unless the tool designer has a forging drawing, a "lead," or a rough forging, he may not be able to make sufficient allowance in his jig or fixture to take care of the excess metal mentioned.

A fundamental principle in tool design is, that *a rough casting or forging must not be supported on more than three fixed points.* Let us consider the work shown at *A* in Fig. 14, which is a rough casting of triangular shape to be drilled in the three corners

where the bosses are located. Now in setting up this work in a jig we shall apply the principles mentioned above and use three points as a support. These three points will come directly under the three holes *D*, *E* and *F* and they may be made in the form of bushings as illustrated at *G* in the lower part of the figure. Now let us consider that we have located the work in one plane but we must also make sure of its location in the other direction. Probably the easiest way to locate it is by means of the pins *H*

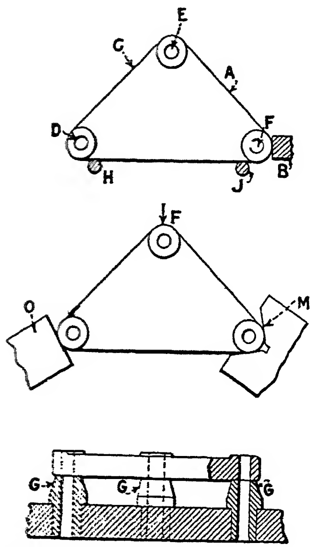


Fig. 14. Locating Rough Work

and *J* and by placing a square stud or block at *B*. In clamping the work, pressure can be applied at one point in the direction *C* as indicated by the arrow, so that this clamp will force the work over against the pins *H*, *J* and *B* and hold it there positively. The other method of locating the same piece is shown in the center of the illustration. In this case one corner of the work is located in a V-block *M* and the other corner comes against the angular block *O*. Pressure is applied at the point *F*. It is understood that the method of setting up on the three bushings is the same in either case.

Locating a Piece of Rough Work Having a Hub Cast on It.—Referring to Fig. 15, another piece of work is shown which

has a rough hub cast on it and extending beyond the flange of the work *A*. Now this piece is also a rough casting and in order to obtain a true relation between the hub and the rest of the casting it is necessary to use the hub in setting up the work. By referring to the upper figure it will be seen that we do not depart from the three point method of setting up on the pins indicated at *C*. At the same time however the necessity for con-

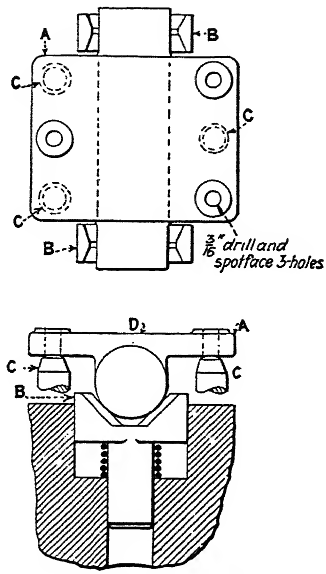


Fig. 15. Locating a Piece of Rough Work Having a Hub Cast on It

sidering the hub makes it advisable to provide a means for locating it on the spring V-blocks *B*. By applying pressure at *D* the work will seat itself on the three points *C* and will also locate in the spring V-blocks. In connection with the V-blocks mentioned it is well to note that these should be made with a so-called "knife-edge."

Locating a Rough Forging.—Very frequently rough forgings are made with the locations of drilled holes indicated by a countersunk spot. Fig. 16 shows a gear blank with the center hole countersunk in this manner. In cases of this kind it is common practice to set the work up and hold it by the outside *B* in a floating chuck. When this is done the chuck is placed on a

drilling machine and the drill centers itself in the countersunk hole, thus making a jig unnecessary. It is sometimes found advisable where very much of this work is to be handled and when the drilled hole is long, to provide a supplementary bushing, supported on the column of the drilling machine in order to steady the drill and prevent it from "wabbling." The manner in which this is accomplished is clearly shown in the illustration.

Another condition sometimes found in machining a rough

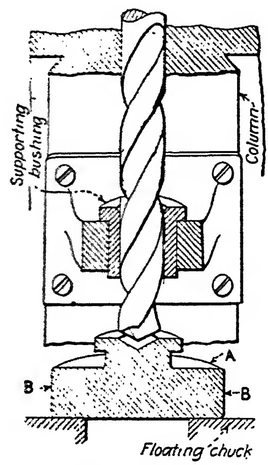


Fig. 16. Forging of Gear Blank with Hole Countersunk

forging is indicated in Fig. 17. In this case a steering knuckle *A* is the part in question and it is necessary to drill through the center of the long hub indicated. One end of the hub is located in the cup bushing *B* while the other end seats itself in the screw bushing *C*. Now this particular case is given as an example of a method which should not be used. In the first place a screw bushing is not very good practice because it is not sufficiently accurate and it is likely to become clogged with chips and in the second place the method shown is dependent for its accuracy on the regularity of the two ends which seat themselves in the bushings. If these ends are not uniform the work will not be true in the bushings and as a consequence there will be a variation in the relation of the hole to the arm *D*, such that the latter may be out of line and will not clean up in the subsequent opera-

tion of turning the portions marked *f*. A much better way to locate a forging of this sort would be to locate it with a knife-edge V-block at each end of hub *A* so that when the hole is drilled it will be true with the hub and in correct relation to the portion *D*.

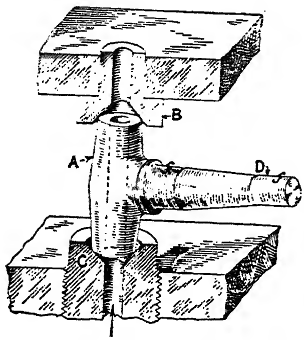


Fig. 17. Incorrect Method of Locating a Forging for Drilling

Location of Finished Work.—When work has been partly machined it is usually necessary to locate it for subsequent operations from some of the finished surfaces or holes. An example of this kind is shown in Fig. 18, in which the connecting rod *A* has been previously machined as indicated by the finish

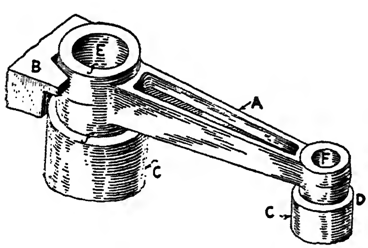


Fig. 18. Location of a Connecting Rod Forging

marks. As these surfaces have been previously faced and as it is necessary to drill the holes *E* and *F* so that they will be true with each other and with the surfaces machined, the work must be set up with this point in mind. By allowing it to rest on the bushings *CC* the relation desired can be readily obtained. It is, however, necessary to obtain a location for the hole *E* and

at the same time make sure that this location will not disturb the seat on the two bushings *CC*. This can be done by using a V-block as shown at *B* having a bearing which touches the hub above the parting line of the forging. When pressure is applied at *D* the effect will be to throw the hub over into the V-block and at the same time the angularity on the hub will tend to draw

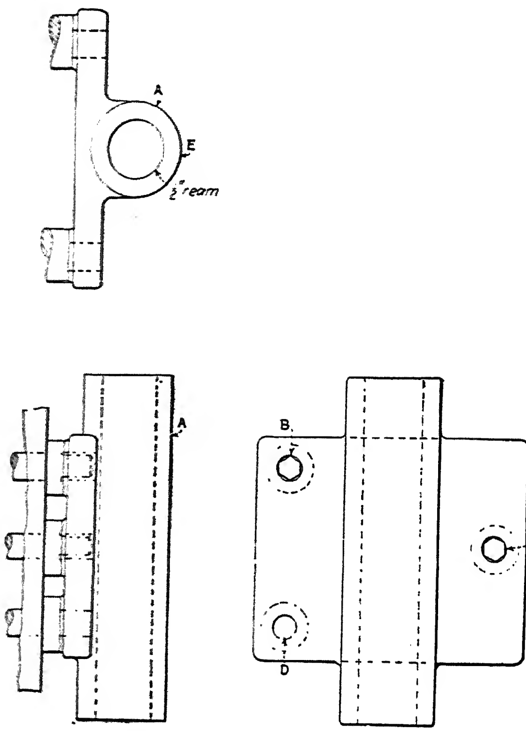


Fig. 19. Location of Finished Work

it down on to the bushing *C*. It is not usually considered good practice to drill and ream the hole *E* and the small hole *F* in the same operation and it is customary to locate the hole *F* from the previously machined hole *E* and to do the work in another jig.

Fig. 19 shows another method of locating finished work. It will be noted that this piece is the same as that shown in Fig. 15, and the operation to be done in this case is the drilling of the long hole in the hub *A*. The holes *B*, *C*, and *D* have been drilled

and reamed in a previous operation. It will be remembered that we were careful to locate the work for the first drilling by means of the long hub and as a consequence we can now use the holes drilled in the previous operation for locating the piece when drilling the long hub. By setting the work up on pins at *B* and *C* we obtain the alignment and the stud *D* simply acts as a support. If there were to be other operations on this piece it would be advisable to use the holes *B* and *C* to locate from through all the subsequent operations.

Fig. 20 shows another example of a method of locating a piece

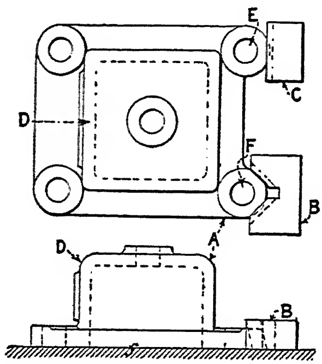


Fig. 20. Location of a Finished Casting

of work of which the surface *f* has been machined in a previous operation. The work is shown at *A* and it is located on the finished surfaces indicated as it is necessary to keep the holes square with the finished surfaces. At the same time we wish to make certain that the holes are drilled in the right relation to the hubs *E* and *F*. Therefore we use a V-block *B*, slightly undercut at an angle of about 10 deg., in which to locate the hub *F*. The hub *E* will swing over against the block *C* which is also slightly undercut. Now when pressure is applied in an angular direction as indicated by the arrow at *D*, the work will not only seat itself on the finished surface but will be forced over into the V-block *B* and against the angular block *C* thus assuring a positive and accurate location.

Correct Side from Which to Drill Holes.—There is a very important point which should always be considered in the location of holes in two adjacent pieces, when these holes pass

through both pieces and are used as rivet or bolt holes to hold the two pieces together. An example of this kind is shown in Fig. 21. In this case the two disks *A* and *B* shown in the first part of the illustration, are held together by rivets passing through the holes *C* and *D*. It is evident then that these holes must be in alignment. Now let us assume that the work *B* is placed in the jig so that it is drilled from the side *E* and in the direction indicated by the arrow. When this is done it is evident that the drill may "run" a trifle so that the holes may take a slightly angular direction as indicated. Now if the upper pieces *A* were to be drilled from the side *F* and in the direction indicated by the arrow there is a possibility that these drilled holes might also run out a trifle. The result would be that when

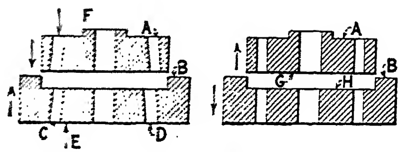


Fig. 21. Correct and Incorrect Methods of Drilling Holes in Finished Adjacent Parts

an attempt was made to assemble the two parts *A* and *B* they would be out of alignment and it would be impossible to put the rivets in place to hold the two parts together.

Assuming that both parts *A* and *B*, as shown again in the other part of the illustration, are drilled in each case from the sides *G* and *H* which are adjacent to each other, then it is evident that at the points where the drill starts in each case the holes will coincide.

Distortion Caused by Improper Clamping.—The matter of distortion must be considered when locating and clamping any piece of work. Several examples of this kind are shown in Fig. 22. Referring to the upper illustration the lever *A* is located on a stud *B* and is clamped at the end *F* by means of the clamp screw *E* which throws the work over against the stud *D*. Now it will be seen that when pressure is applied in the direction indicated by the arrow it cannot cause distortion or change of shape in any way. On the other hand referring to the illustration below, if the work *A* were to be located on a stud *B* with a sliding V-block *G* used as a locater and clamper, it is evident

that the pressure applied in the direction indicated by the arrow might very easily tend to distort the work as shown by the dotted lines in the lower portion of the illustration. These are points which are frequently neglected by a tool designer.

Clearance Around Work.—When designing, the matter of clearance around the work between the walls of the jig and the work must be given careful consideration. An example to illus

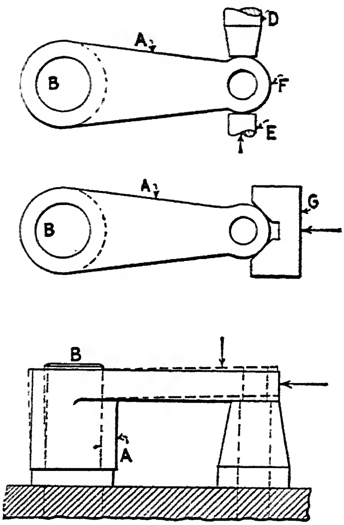


Fig. 22. Correct and Incorrect Location and Clamping

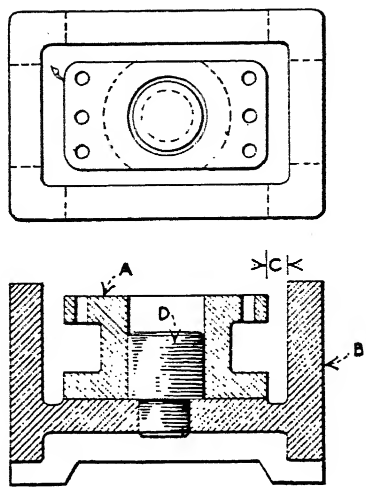


Fig. 23. Clearance Around Work

trate this point is shown in Fig. 23. In this case the work *A* is located on a stud *D* placed in the body of the jig, which is made of cast iron. Now assuming that the work *A* is a casting, there is likely to be some variation in its outside dimensions; if the jig body *B* is also a casting there is likely to be some variation in its dimensions as well. Therefore the clearance as indicated at *C* between the walls of the jig and the work should be ample to allow for variations in the castings. As a general thing the distance *C* should never be on a small work much less than $\frac{3}{8}$ in., that is to say on a piece of work having dimensions about 4 x 6 in. On larger work which may run to 18 or 20 in. or even more the clearance would be correspondingly greater. The writer has known of several cases within the last year where the clearance around rough castings of large size has not been sufficient

to take care of variations. In one case the matter became so serious that it involved practically the rebuilding of a large part of an expensive trunnion jig. It is evident therefore that the matter of clearance around the work in a jig must be given the most careful consideration.

Provision for Cleaning.—Many designers do not pay enough attention to the matter of cleaning a jig. It is evident that when work is being produced on an interchangeable basis by the use of jigs and fixtures there is a great accumulation of chips which must be removed from the jig as each new piece is placed in position. Now, up-to-date production methods call for rapid cleaning and there are several methods in vogue depending on what material is being drilled. Some factories use air pressure while others depend on a can of kerosene into which the workman can dip his jig from time to time, but all of them provide the workman with a brush to keep the jig clean. Now it is obvious that if a brush is to be used to keep the locating surfaces in a jig clean it is important to be able to reach these surfaces with the brush. If this is not possible the jig must be made open so that the chips can be washed out as they accumulate. Locating pads or points should be built up above the surface of the jig.

A simple type of jig is shown at *B* in the upper part of Fig. 24. In this case the work *A* rests on a stud but the walls of the jig surround it so that it cannot be easily cleaned. The designer, however, by coring some openings at *C* provides means of washing out the chips without difficulty. In the lower part of the illustration the work *E* is a finished piece which is located on a center stud *F* supported on four points *D*. These points are built up above the surface of the jig so that they will not be apt to accumulate chips and they can also be very easily cleaned. Do not neglect the matter of cleaning when designing a jig.

Wear on Locating Surfaces.—When jigs are used for a great number of pieces as frequently happens in high production methods, the matter of wear and the accuracy depending thereon must always be considered. Not only should locating points on surfaces be so made that they can be replaced by others when worn, but also the manner in which they are likely to wear should be given attention. An example of this kind is shown

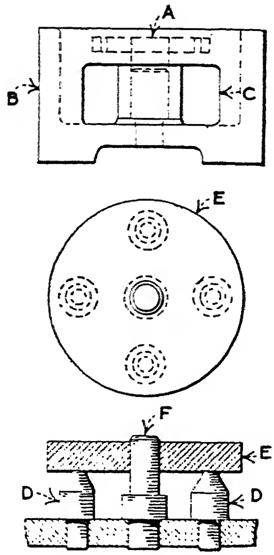


Fig. 24. Provision for Cleaning

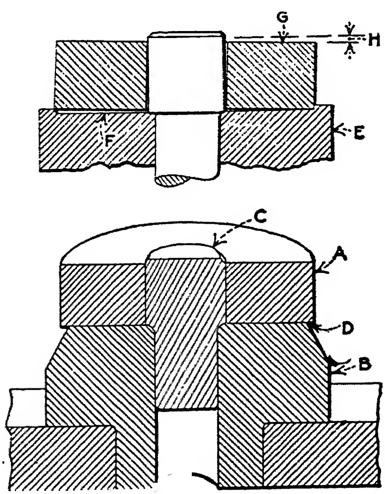


Fig. 25. Provision for Wear on Locating Surfaces

in Fig. 25, in which the work *A* is a finished piece which locates on the stud *C* and rests on the hardened locater *B*. Now if this locater is made slightly smaller in diameter than the work so as to allow the latter to overhang a little all around as indicated at *D*, there is no danger of wearing a pocket or recess in the locating member. But if it should be made as shown in the upper part of the illustration at *E* it is very evident that after a number of pieces has been machined a pocket might be worn

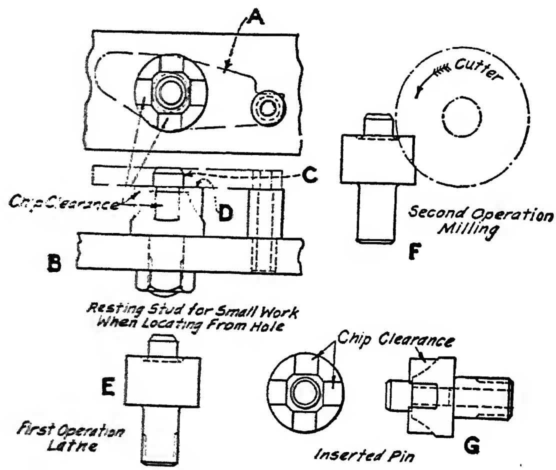


Fig. 26. Method of Making Locating Studs

in the locater as indicated at *F*. In a case of this kind it would be found that the work might take the position shown at *G* and the inaccuracy *H* would result. The tool designer must always consider these points when designing his jig.

Use of Locating Studs.—Fig. 26 shows two methods of making a locating stud for use in a previously finished hole. The work *A* in example *B* locates on the cylindrical portion *C* and rests on *D*. This stud is made of one piece and *E* shows the first operation in manufacture which is done on a lathe; and *F* illustrates how the relief cuts are made by milling. The finished plug presents a broken surface with relief cuts so that chips are not likely to accumulate on the surfaces. The example shown at *G* illustrates another method of making the same sort of a locating plug, using an inserted pin instead of a solid piece, which is often found desirable.

Chip Clearance.—If it were possible to break up the chips when drilling so that they would be in the form of dust there would be very little trouble caused by chips, but as this is not the case suitable provision must be made to take care of them as they are produced. Referring to Fig. 27, an example is shown in the work *A* which indicates the provision which has

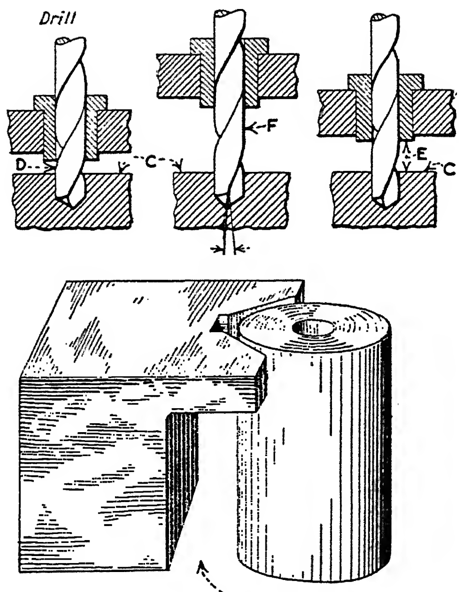


Fig. 27. Chip Clearance

been made in the locating V-block *B* to provide for chip clearance and cleaning. If this V-block extended down the ėntire length of the work *A* it would be very difficult to clean out the chips that might accumulate around the edges of it, but by cutting it away as shown the trouble is avoided.

In the upper part of the illustration several examples of bushings are shown. Let us assume that the work *C* is to be drilled. Now if the bushing is placed too close to the work as shown at *D* there is no chance for the chips to work their way out except by coming up through the flutes of the drill and packing into the bushing. It is good practice to make the clearance between the bushing and the work about one diameter of the drill as shown

at E. Care must be taken however not to go to extremes and place the bushing so far away from the work that inaccuracy may result as shown at F. In this case the bushing is so far away from the work that the drill may run off and produce an angular hole as indicated.

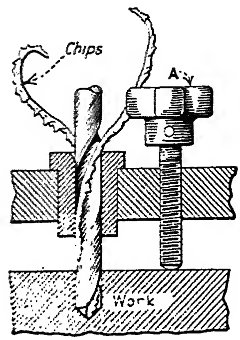


Fig. 28. Peculiar Condition Illustrating Trouble Caused by Chips

A peculiar case in connection with chip clearance is shown in Fig. 28. In this case the work which was drilled was of steel and the chips working up through the flutes of the drill became entangled in the thumbscrew A in such a way as to loosen it, thus releasing the work and causing inaccuracy. It is evident that this could have been avoided by making the screw A a left-hand screw, but this would not be good practice as a left-hand screw is awkward to use.

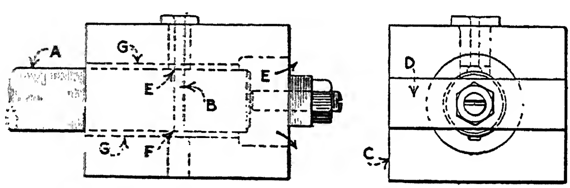


Fig. 29. Burr Clearance in a Cotter Pin Jig

Burr Clearance.—A matter which is frequently neglected by young designers is the making of provision for the burr which is thrown up by a drill as it passes through the work. In many cases this can be neglected as there is no burr to speak of on cast iron or malleable iron. It is particularly noticeable however on jigs for small steel pins, cotter pin jigs and the like. An example of this kind is shown in Fig. 29 in which the work A

is to be drilled at the point *B* and a very simple jig has been made to hold it. The jig is a plain block of steel *C* having a strap *D* across it which contains a stop screw *E* that acts as an end locater. Now it will be seen that when the hole *B* is drilled burrs will be thrown up around the hole at *E* and *F* and if no provision is made for these burrs it will be very difficult to get the work out of the jig after it has been drilled because the burrs will prevent it. The remedy for this is to cut a groove slightly larger than the drill diameter at the top and bottom of the jig as shown at *G*. When this is done the piece can be removed without difficulty.

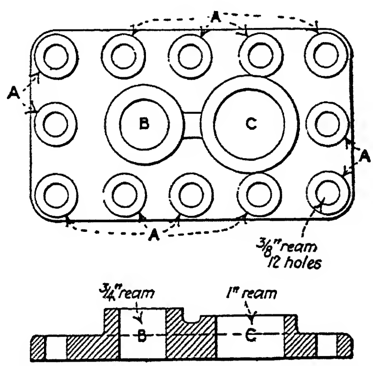


Fig. 30. Size of Holes To Be Drilled in Same Setting

Size of Holes To Be Drilled in Same Setting.—It is not advisable to attempt to drill holes of large and small diameters in the same jig unless conditions are such that the jig is very expensive and it would be costly to make other jigs. In cases of this kind it might be possible to arrange two machines side by side so that the jig can be moved from one to the other in drilling the holes. An example of this kind is shown in Fig. 30 in which there is a series of reamed holes $\frac{3}{8}$ in. in diameter all around the edge of the casting, as shown at *A*. It will be seen that there are also a $\frac{3}{4}$-in. reamed hole and a 1-in. reamed hole in the work. It would be better practice to drill all of the holes *A* in one jig and then to build another jig for the holes *B* and *C*. This point should always be considered by the tool engineer when laying out his operations, but occasionally it is overlooked so that the jig when made is not practical.

Setting up and Removing Work.—It happens occasionally that an inexperienced designer will design a jig and after he has worked it up very nearly to completion he will discover (or some one else will discover) that he cannot get the work into or out of the jig. Naturally this is somewhat embarrassing, so that the point may be brought up at this time that it is well for the designer to bear continually in mind throughout the

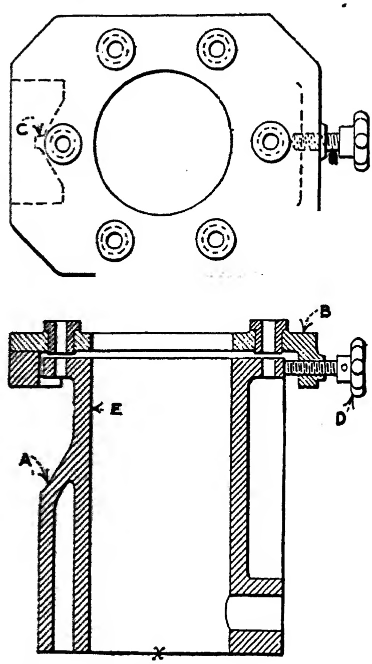


Fig. 31. Set-On or Plate Jig

design of his jig that it is necessary to put the work into the jig and to remove it therefrom. Suitable provision should be made so that the operator can reach in and remove the work without difficulty or else an ejector should be provided to take care of the matter.

Types of Jigs.—There are various types of jigs in common use and these will be dealt with in detail in their proper sequence. It is not easy to make a broad distinction between some of the types of jigs, but speaking generally they may be divided into the following: Plate and templet jigs; cast jigs, open and closed;

built-up jigs; trunnion and indexing jigs, and standard jigs. A brief discussion will be given of each of these types.

Plate and Templet Jigs.—One of the simplest types of jigs is a "set-on" or plate jig, illustrated in Fig. 31. Jigs of this kind are used on heavy castings where one end is to be drilled with a few holes and when the other end is finished so that it can be used as a surface on which to set up the work. In the illustration shown *A* is the work and *B* is the jig. This particular jig is made of cast iron and has a steel V-block located

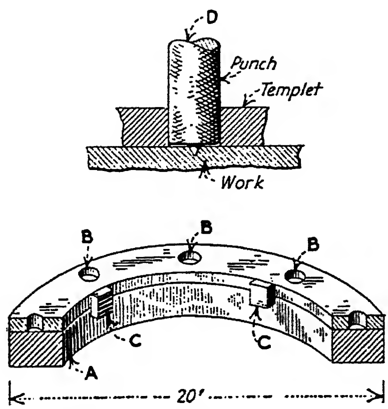


Fig. 32. Templet Jig for a Large Ring

as shown at *C* which is used to locate the jig in relation to a boss on the casting. A thumbscrew *D* is provided at the opposite side in order to make the jig fast to the work and draw it up tightly into the locating block. We might easily imagine a condition in which the hole *E* had been previously machined, thus allowing a plug to be dropped down into the hole to use as a locater instead of working from the outside bosses with a V-block as shown.

A templet jig is generally used with a prick punch to locate a series of holes on some pieces of machine work where only a few are required. An example of this kind of jig is shown in Fig. 32. In this case the work *A* is a large ring which has a number of holes *B* drilled in it here and there on the surface of the ring. The templet jig is made of sheet metal and is located in the work by means of several lugs such as those shown at *C*. A special punch like that indicated at *D* is used to mark

the centers of the holes by placing it in the templet and striking it a blow with a hammer. After the work has been completely marked the templet is removed and the drilling is done on a drilling machine.

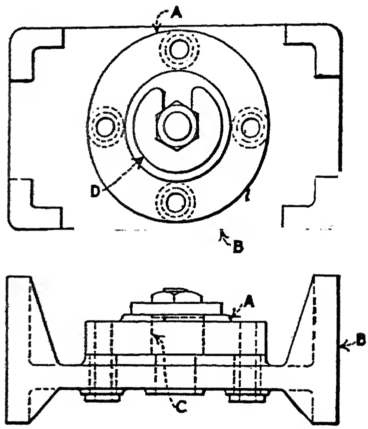


Fig. 33. Open Jig Type

Open Jigs.—A very simple type of open jig is shown in Fig. 33. Jigs of this kind are used for simple pieces which can be easily clamped and which have only a few holes to be drilled. In the case shown the work *A* is located by means of a center stud *C* and is clamped down by the C-washer *D*. After this has

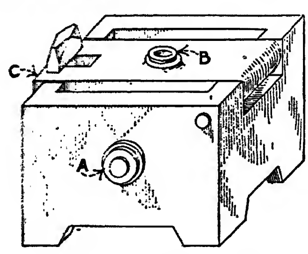


Fig. 34. Closed or Box Jig

been done the jig body *B* is turned over and the work is drilled from the other side.

Closed or Box Jigs.—The type of jig shown in Fig. 34 is usually termed a box jig. The body of the jig may be all steel or cast iron but in the case shown it is cast iron. Bushings are inserted as at *A* and *B* and a hinge or leaf *C* is provided which

sometimes acts as a clamp to hold the work in place, but more frequently it simply provides means for removal of the work after it has been drilled. Jigs of this kind are commonly used for small parts and light drilling.

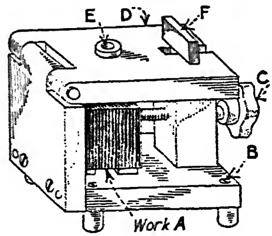


Fig. 35. Built-Up Jig

Built-up Jigs.—Fig. 35 shows quite a different type of jig as this is made up of separate pieces of stock which are screwed and doweled together. The advantages of this type of jig are that it can be readily made and that it has many advantages from the viewpoint of replacements when worn. In the particular jig shown, the work *A* rests on the steel base *B* and is held in

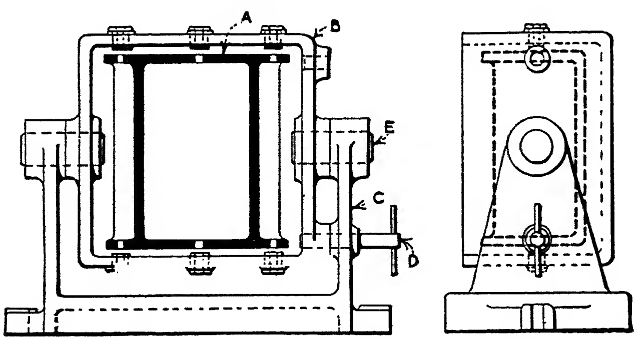


Fig. 36. Trunnion Jig

place by means of the thumbscrew *C*. The leaf *D* has a bushing at *E* and it is located and held in place by the quarter-turn thumbscrew *F*. A jig of this kind can be easily cleaned in addition to its other advantages.

Trunnion Jigs.—In the drilling of automobile cylinders, transmission cases, housings and many other large castings having holes drilled from several sides and possibly at various angles, a trunnion jig is usually found the most desirable, because after

the work has once been placed in the jig all of the holes can be drilled before it is removed and as a consequence correct relation between the holes will always be assured. A simple type of trunnion jig is shown in Fig. 36. In this case the work *A* is located in the cradle *B* which in its turn is mounted on the trunnions at *E*. As the various holes are drilled the index pin *D* is

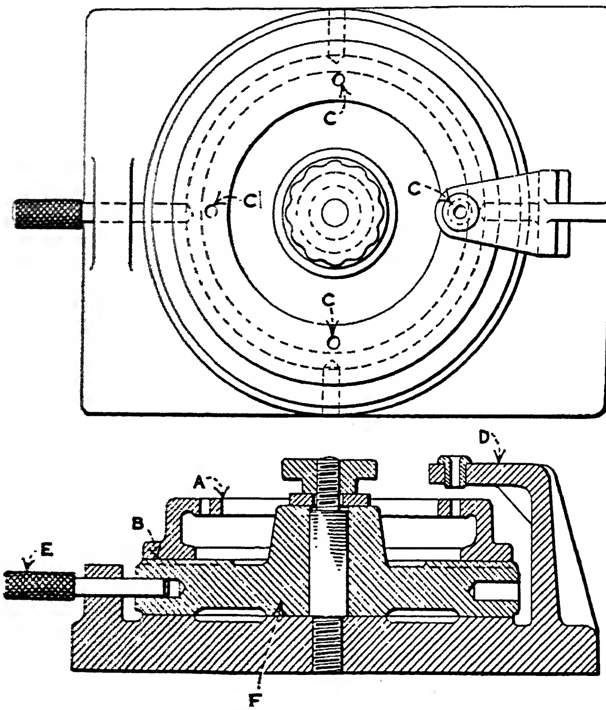


Fig. 37. Indexing Jig

removed and the portion *B* is turned over into such positions that the desired bushings come uppermost.

The correct location is assured by means of the index pin which is generally inserted in a bushing in order to insure accuracy. Trunnion jigs are made in great variety and the example shown to illustrate the type is a very simple one.

Indexing Jigs.—An indexing jig is somewhat different from a trunnion jig in that the work is indexed into different positions for drilling a series of holes usually through the same bushing. A case of this kind is shown in Fig. 37 in which the

work *A* is located by means of some previously drilled holes in the surface *B*. In this case there are four holes to be drilled at *C* and one bushing located in the bracket *D* in the correct relation to the center of the work. A jig of this kind is supposed to be strapped or clamped to the drilling machine table and the work is indexed by pulling it around until the index pin *E* enters the various holes in the revolving member *F*.

Occasionally index jigs are made when two or more holes are close together and a series of these holes is required at equally spaced intervals around the parts. Many methods of indexing are in use and the example shown is a very elementary type. Other instances will be given under their proper heading.

CHAPTER III

DETAILS OF DRILL JIG CONSTRUCTION

PLAIN CLAMPS—MULTIPLE CLAMPS—HOOK BOLT AND WEDGE CLAMPS—EQUALIZING CLAMPS—SPRING PLUNGERS AND JACKS—V-BLOCK DESIGN—LEAF JIG DESIGN—LEAF CONSTRUCTION—CLAMPS IN THE LEAF—LEAF STOPS—LEAF LOCKS—STANDARD JIGS AND COMPONENTS—JIG BODIES—STANDARDIZATION OF JIG POSTS AND THUMBSCREWS—JIG FEET—LOCATING PLUGS—TYPES OF BUSHINGS—BUSHING DESIGN AND PROPORTION—METHODS OF HOLDING SLIP BUSHINGS—STANDARD KNOBS AND THUMBSCREWS—EJECTORS.

In locating a piece of work in a jig there are several points which must be looked after very carefully, in order that the piece may seat itself properly, may locate against portions of the casting which are not likely to vary and may be clamped securely without any danger of distortion. We have gone very thoroughly into the principles of locating the work in a previous chapter and we have taken up the various points which influence the design of a satisfactory jig. It must be borne in mind that there are numberless varieties of clamps which are used for various conditions found in jig work in many factories throughout the country and that it is the selection of the proper type of clamp which shows the skill of the designer.

It is of primary importance that the clamp should not tend to force the work away from the locating points when pressure is applied to it. It very frequently happens that the bearing which the clamp obtains on the work is not quite what it should be and as a consequence the work is forced away from its bearing and locating points so that inaccuracy is the result. In handling delicate work it is important that the clamp should not be applied to any portion which is likely to spring out of shape or to be distorted, making the finished product inaccurate.

Great care must be exercised when several clamps are applied on different portions of a piece of work. When a condition of this kind arises the clamps must be designed in such a way that they will equalize and distribute the pressure so that the work will not be tilted out of its true position.

Plain Clamps.—In Fig. 38 are shown both correct and incorrect methods of clamping. With the work *A* set up on lugs at *C* and *D*, the clamping action should be directly over these points as shown at *E* and *F*. Pressure should never be applied at point *G* for the reason that it would be apt to distort the work so that it might take the position *B*. This is a principle in designing but it does not apply to every case. We might easily imagine a

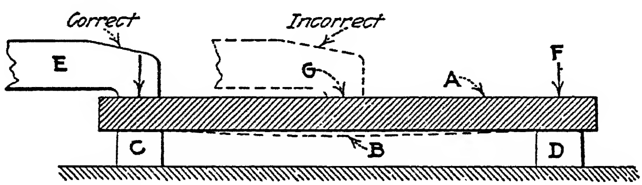


Fig. 38. Correct and Incorrect Methods of Clamping Work

heavy piece of work which could be clamped at *G* without causing any trouble. On light work the principle mentioned must be very carefully adhered to.

Several types of plain clamps which are commonly used in jig design are shown in Fig. 39. These clamps may be varied to suit particular conditions; that is they may be bent into different shapes and they may be operated by means of a screw in the middle or at the end, or they may be pivoted. They may be shaped to conform to a peculiar casting and they may have a very narrow bearing point where they come in contact with the work. In fact they may be changed to suit an infinite number of conditions. There is shown at *A* a clamp commonly called a U-clamp which is made of a single piece of steel bent into a U-shape. This type of clamp is frequently used in faceplate work, and on milling machines or boring mills, using a T-bolt as indicated. The clamp shown at *B* has a guide and support at *C* which prevents it from turning and getting out of position with the work when it is not used. The slot at *D* allows the clamp to be pulled back away from the work after

the piece has been machined. This type of clamp is in common use for many varieties of jig work.

The clamp shown at E is similar to B but it is operated and guided in a different manner. The operator applies pressure

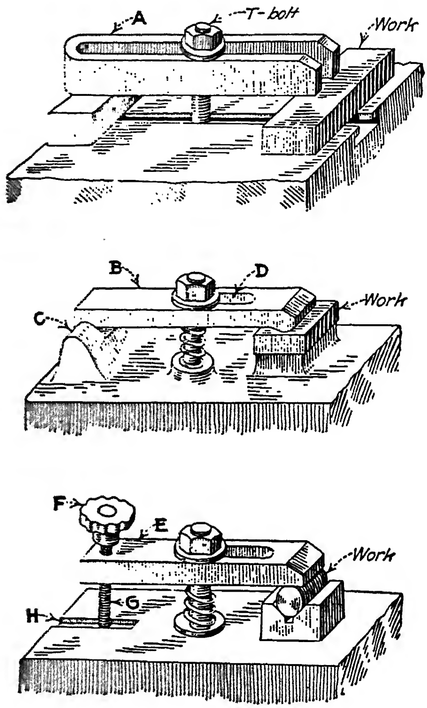


Fig. 39. Types of Plain Clamps

to the clamp by means of the thumb-knob F on the end of the screw G. When releasing the work the screw slides along in the groove at H. This groove also serves to keep the clamp in alignment with the work when clamping.

Hook-Bolt and Wedge Clamps.—At A in Fig. 40 is shown a hook-bolt clamp, frequently found very convenient for work not easily reached with the ordinary form of clamp, or when there is not room enough to permit the use of a plain clamp. In using a hook-bolt the heel B of the hook-bolt should be "backed-

up" so as to take the pressure resulting when the clamp is tightened. Unless provision is made for taking up pressure there is a possibility that after continued use the hook-bolt may become bent so as to be practically useless. There is a tendency on the part of tool engineers to avoid the use of hook-bolts for this reason. We consider however that a hook-bolt is too useful an adjunct to be cast away. There is no objection whatever to

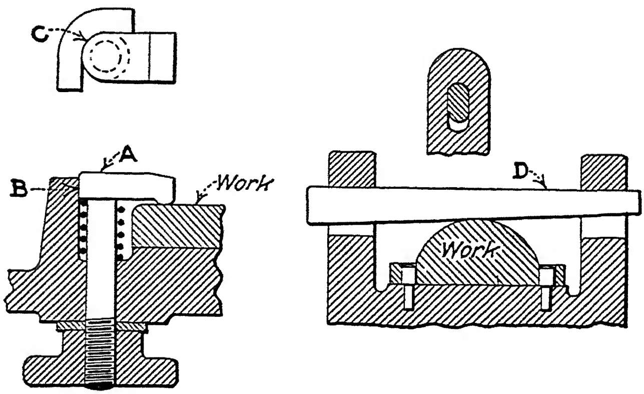


Fig. 40. Hook-Bolt and Wedge Clamps

a hook-bolt when it is backed up as shown by the upper view at *C*, as the strains of clamping are taken by this backing up lug so as to prevent any bending of the hook-bolt. When used in this way it will be found that many problems in clamping are simplified.

A wedge clamp is shown at *D* and although this form of clamp is not recommended for all work there are certain cases where it can be applied to advantage. The wedge is likely to distort the work or the jig, but in certain cases suitable provision can be made to counteract this distortion in the fixture and when this is properly done no difficulty should be experienced in its use. There are certain factories in the country which use jigs with wedges to a considerable extent. Sometimes a wedge is hung by a piece of closet chain and fastened to the jig so that it will not be lost. At other times the wedge is made extra long and pins are inserted at each end to prevent its being lost or falling out of the jig.

Suggestions for Clamping.—Fig. 41 shows a group of representative clamps which can be applied to many varieties of work. These illustrations are diagrammatic and serve to show princi-

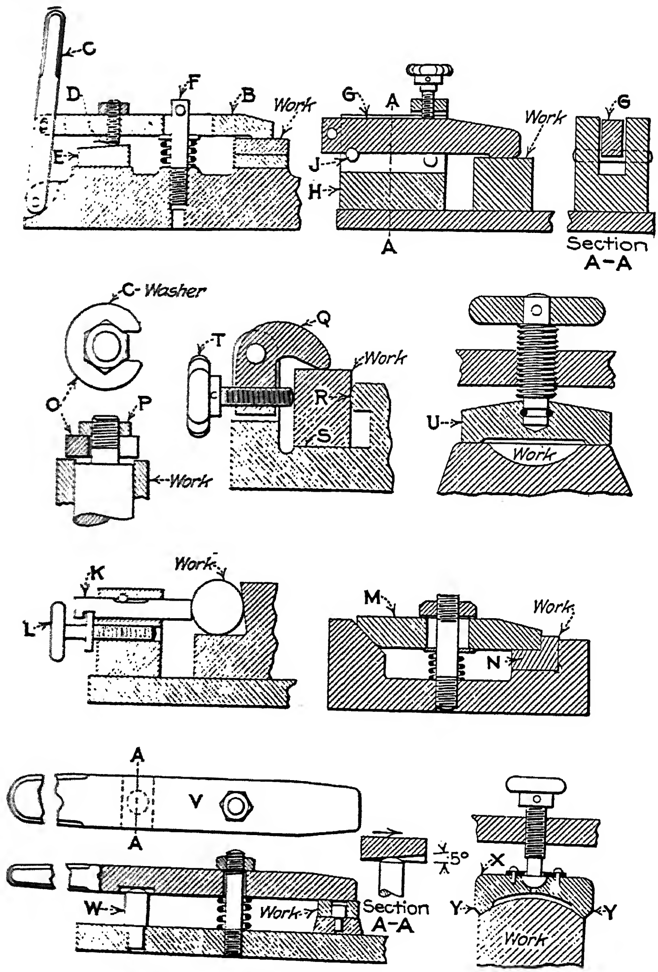


Fig. 41. Group of Representative Clamps

ples rather than careful details. The clamp *B* should not be used except when the work is located over pins or in some other way which prevents it from moving when the clamp is applied. This particular clamp is operated by a lever *C* and slides for-

ward on the work as the stud *D* rides up on the angular hardened block *E*. A pin or nut on the end of the stud *F* takes the pressure of the clamp.

A somewhat similar arrangement is shown in the clamp *G*. It is somewhat more elaborate but has the advantage of being made up in unit form so that it can, if necessary, be standardized and made up in quantities when the occasion warrants. The section *A-A* shows another view of the block with the sliding clamp in position in the block *H*. In operation the clamp is slid forward until it comes to rest over the pin *J*, after which pressure is applied by means of the thumbscrew. It is an excellent clamp which is easily operated and a form similar to it is used in great quantities by one very large manufacturing concern in the Middle West.

In order to avoid throwing a piece of work out of alignment when clamping, the scheme shown at *K* can be used. The work locates in a V-block and the pin *K* is adjusted by means of the collar screw *L*. This type of clamp applies the pressure directly to the work without any turning action.

The clamp shown at *M* is not used frequently, but there are occasions when a piece of work like that shown at *N* can be held to advantage by this type of clamp. The objection to it is that it must be loosened considerably in order to remove the work unless it is possible to slide the piece out of the jig end-wise.

The C-washer clamp shown at *O* is too common to need much description. In its simplest form it is a washer, cut out on one side so that when the nut *P* is loosened it can be slipped out readily. After this the work can be removed without difficulty and without removing the nut.

The clamp shown at *Q* is very useful on small light work. It is rapid in its action and serves to clamp the work at *R* and *S* at the same time. When the thumbscrew *T* is operated equal pressure is brought to bear in the directions indicated by the arrows. Particular attention must be paid to the position of the points of contact in relation to the pivot pin or more pressure will probably be applied in one direction than in the other.

The clamp shown at *U* is commonly called a "button" clamp. It is useful for small work and is so made that the portion *U* does not revolve but is hung loosely on the end of the screw so that when pressure is applied it adjusts itself to the work. The

button may be made large or small according to conditions. It is a useful clamp and is found in many varieties of light jig construction.

A somewhat peculiar type of clamp is shown at *V* whose use is limited to finished work. Furthermore the work must be positively located in order that it may not be forced out of position by the action of the clamp. The operation in clamping is a swinging one as indicated by the arrow and the clamp is so made at the point shown in section *AA*, that a wedging action takes place between the clamp and the top of the pin *W*.

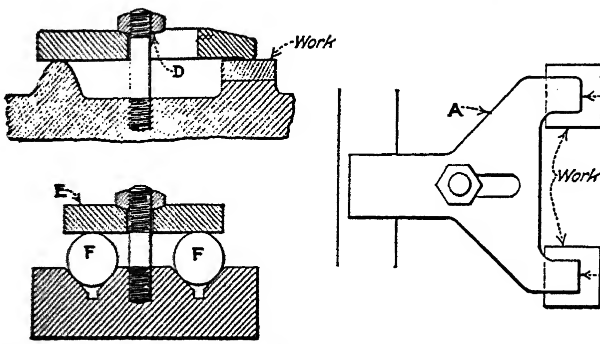


Fig. 42. Multiple Clamps

Another type of clamp, with a "button" end as shown at *X*, is similar to that shown at *U* except that the screw which operates it has a ball-end as indicated, in addition to which the clamp itself is made with three points *Y* separated 120 deg. so that the three points will bear with uniform pressure on a regular surface. A clamp of this kind is frequently used for holding the round end of a piston in automobile work, but other applications may frequently be found in the general run of jig work.

Multiple Clamps.—It is frequently necessary in clamping a piece of work to apply pressure simultaneously at two points which are widely separated. Sometimes the clamp is applied to two pieces at the same time while at others it may be at two points on the same piece of work. The example *A* shown in Fig. 42 is of a plain clamp spread out at the end so that the points *B* and *C* bear on the work. If the work has been machined it is unnecessary to provide anything more than a plain nut for clamping, but when the work is "in the rough" it is

advisable to provide for inequalities by making the portion *D* in the form of a ball so as to permit the clamp to float enough

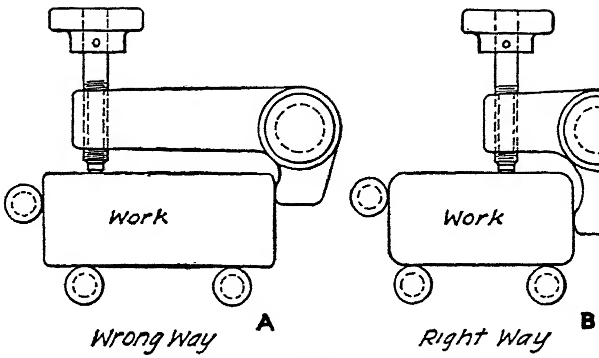


Fig. 43. Correct and Incorrect Method of Using Double End Clamps

to take care of the inequalities in the casting. The clamp *E* is commonly used to hold two pieces of work at the same time as indicated at *F*. It can be swung around side-wise after the work is machined to allow the pieces to be removed.

Fig. 43 shows correct and incorrect methods of using the double end clamp. When clamps of this kind are to be used the two points which bear against the work should be as nearly the same distance from the center as possible. In the exaggerated example shown at *A* the clamp is so proportioned that it would be apt to dislocate and force the work out of its correct location. The example *B* shows a properly designed clamp for the same piece of work.

Equalizing Clamps.—When it is necessary to hold several pieces at the same time or to apply pressure equally to three or four pieces at the same time, an equalizing clamp must be used. It is difficult to illustrate all of the various types of equalizing clamps which are used in jig work, but the principles underlying the design can be simply shown as in Fig. 44. In the first part of the illustration, the work consists of two pieces set up and clamped uniformly with the same screw at the same time. When pressure is applied by means of the screw *B*, there is a reaction through the lever *C* on the end of the pin *D* so as to force the clamp *E* down on the work. At the same time the reaction of the screw forces the clamp *F* down on to the work on that side of the jig with an equal amount of pressure.

In clamping four pieces of work a similar principle can be applied as shown at *G*. An equalizing lever is provided at *H*, pivoted at *J* where the leverage is applied. The pressure will be equal on the rods *K* and *L* and also on the clamp *M* and *N* so that the four pieces of work will be held with uniform pres-

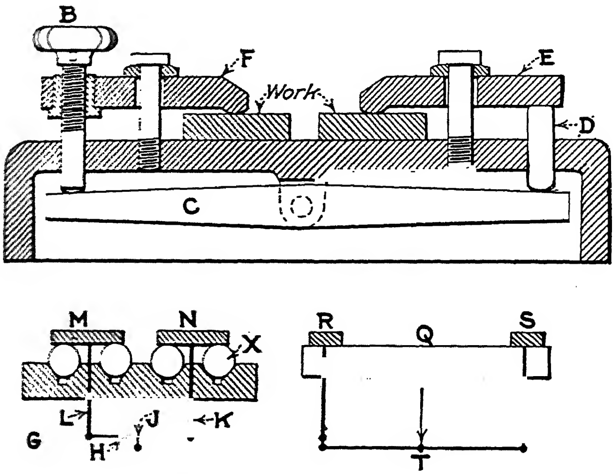


Fig. 44. Equalizing Clamps

sure. The piece *Q* is clamped at both ends at the same time by means of the clamps *R* and *S* when pressure is applied at *T*. By the addition of various levers which must be properly pivoted it is possible to hold a number of pieces at the same time with equal pressure. It must always be remembered however that the power which is applied must be in direct proportion to the number of pieces which are to be clamped. An odd number of pieces is more difficult to clamp than an even number. In order to clamp three pieces at *G* instead of four, it is necessary only to provide a fulcrum at *X* in place of the work.

It is sometimes necessary to locate a piece of work from a certain position with respect to the clamp. An example of this kind is shown in Fig. 45 in which the work *A* locates against an adjustable stop *B* directly in the clamp. The screw *C* holds the work down as shown.

Spring Plungers and Jacks.—In supporting a piece of work in a drill jig or a milling fixture some of the points of support

must be made adjustable when the work is a rough casting. There are also a number of cases where jacks and spring plungers are used not only as a support but also to throw a piece of work over into a certain position. As a general thing spring jacks are made in such a way that they can be positively locked after they have reached a given position, so that there will be no chance of their moving under the pressure of a drill or milling cutter. The locking device used to hold the jack in position is of primary importance. Whatever method of lock-

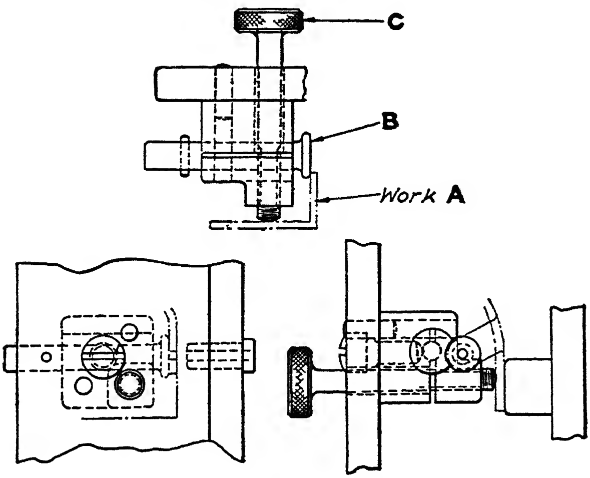


Fig. 45. Clamp for Holding and Locating Work

ing is employed it must be such that there is no tendency to produce in the jack a hole or depression that might make it likely to assume after a time one position regardless of the position of the work against which it acts. Many ingenuous arrangements are used.

There is shown at *A* in Fig. 46 a common type of spring jack. Common as this type is, it is open to some objections. The plunger or jack *B* is usually pack-hardened so that it has a soft core. Therefore the action of the round end screw *C* has a tendency, after considerable use, to make a depression or pocket as indicated by the dotted lines at *D*. It is important that the angular surface against which the screw acts should not be too great. As a general thing about 5 deg. is sufficient. Speaking

generally, we do not favor this type of jack on account of the objection mentioned.

The jack shown at *E* is very similar in general construction except that it has a pocket for the spring, so that it can be used in more confined situations. There is an added improvement also in that the locking pressure is applied through the soft brass member *F* acted upon by means of the screw *G*. There is no turning movement to the plug *F* as it comes against the jack, therefore it is not likely to wear a perceptible depression.

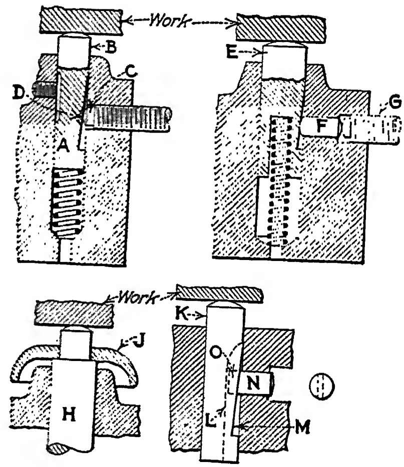


Fig. 46. Spring Plungers and Jacks

The jack shown at *H* is practically the same in construction but it is provided with a shield *J* in order to guard against chips and dirt working down into the bearing and causing it to become loose. A protecting cover can be applied to almost any type of jack, but it is necessary only where the jacks are to be used for a very great number of pieces.

Another type of jack, shown at *K*, is milled on one side to form a support as shown at *L* and is also provided with angular surface *M* against which the plug *N* acts. The plug is made with a tongue so that it enters the slot *L* and prevents the jack from turning. The plug *Y* is also cut so that its angular surface bears against the angularity of the jack. There are cases when a jack of this kind may be found very useful.

In Fig. 47 an entirely different type of jack is shown at *A*. Such jacks are used extensively on light work such as typewriter and cash register parts. In the hands of a careful workman they will give good results but they can be made to distort the work considerably unless properly used. The jack is operated by pushing the plunger *B* forward by means of the knob *C*. The workman must know by the "feeling" that he has applied all the pressure necessary after which he turns the knob *C* slightly which causes the taper pin *D* to expand the end of the

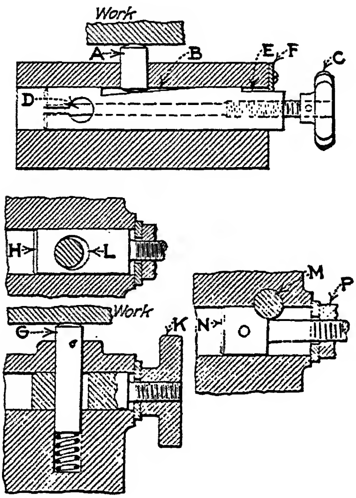


Fig. 47. Adjustable Jacks

plunger *B* so that it locates firmly. The end of the plunger *B* is flatted off at *E* and a plate *F* is provided to prevent it from turning.

An excellent type of jack is shown at *G*. The binding or locating action is produced by drawing up on the plunger *H* by means of the knob *K*. The hole *L* shown in the upper view is usually made about 1/32 in. larger than the jack. A jack of this kind will exert a great deal more pressure, but it is somewhat more expensive to make than some of the others mentioned. It is apparent that when considerable pressure is required the knob *K* can be replaced by a nut that can be tightened by a wrench.

Another type of jack is shown at *M*. It is similar in general

construction to the one just described, but the location action is somewhat different. The plunger N is concave at O to the same radius as the jack so that when pressure is applied by means of a nut at P the friction against the jack is sufficient to keep it from slipping. There are other designs which can be used for spring plungers and jacks but the ones illustrated are more commonly used in jig work.

Fig. 48 shows a method of clamping two jacks simultaneously.

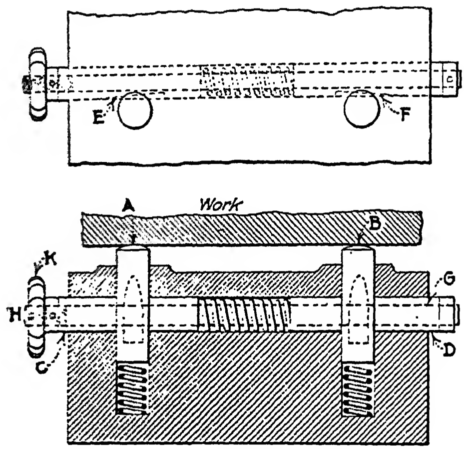


Fig. 48. Locking Two Jacks at One Time

Assuming that the jacks are bearing on the work at A and B in such a way that it is necessary to lock them at the same time in one operation, the method shown can be used to advantage in many cases and other developments can be made to suit particular conditions. In the case shown the locking devices consist of two sleeves at C and D. These sleeves are tapered slightly on one side at the points E and F to engage with the tapered portions of the jacks A and B. Rod G extends through both of the sleeves and is threaded at the end H so that when the knob K is turned the two sleeves approach each other and bring equal pressures to bear on the angular portions of the jacks. A nut can be used in place of the knob.

V-Block Design.—Many types of V-blocks for locating and clamping are found, several of which are shown in Fig. 49.

The type shown at *A* is found in every toolroom and is used for various jobs on the milling or drilling machine. Clamping action in setting up a piece of work, such as shown at *B*, should be in the direction indicated by the arrow. It is not, however, necessary to have the pressure of clamping through the center of the V-block as it may be a trifle to one side or the other without causing any inaccuracy in the work. Another type of V-block, shown at *C*, is very useful in jig work. The angle is slightly less than a right angle and as a consequence pressure applied in any direction indicated by the arrows will force the

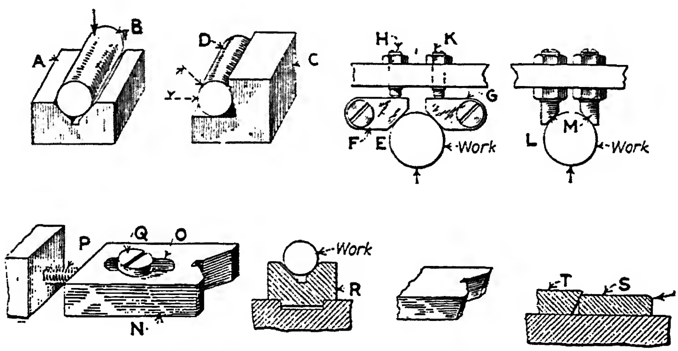


Fig. 49. Types of V-blocks

work *D* directly into the block. This type is commonly used for small work.

An adjustable V-block is shown at *E*. The blocks *F* and *G* are pivoted on the studs indicated and may be adjusted by means of the headless screws *H* and *K*. After the adjustment the check nuts must be tightened to make the location permanent.

Still another type of adjustable V-block, shown at *L*, will need two round pins cut at an angie at the point *M*. This type of *V* can be adjusted by means of the check nuts. The objection to this type, and also to that shown at *E*, is that there is always a possibility of the nuts loosening so as to cause variation in the location.

The principle of a sliding V-block is shown at *N*. The block has a slot at *O* which permits adjustment. Pressure can be applied through the screw *P* to adjust the block. An arrangement of this kind is not good on account of the opening at the slot

which allows chips to accumulate, causing considerable trouble. Furthermore, practically all of the pressure applied by the angular jaws is taken on the head of the screw *Q*. If it becomes necessary at any time to use a block of this type it should be tongued as shown at *R* and a suitable sheet metal cover should be placed over the slot to protect it from chips and dirt. When a V-block is made like that shown at *R* there is always a possibility of chips accumulating under the sliding portion so that after a while it can be operated only with difficulty. For locat-

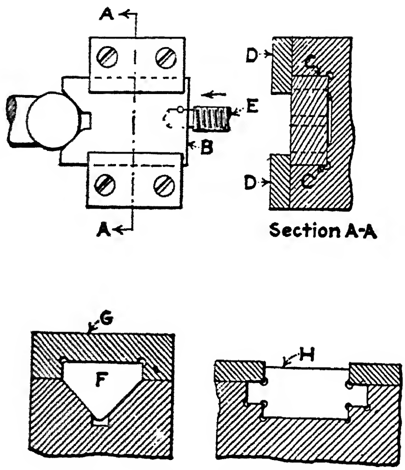


Fig. 50. Sliding V-block Design

ing several V-blocks in line with each other when they are not adjustable they may be tongued as shown. Occasionally a piece of work is located in a V-block and it is at the same time desirable to hold the work down by means of the V-block. An example is shown at *S*, where the work is located by means of the sliding V-block *T*. The block may be undercut to an angle of about 10 or 15 deg., so that it will not only locate the work but will hold it down as well.

At *B* in Fig. 50 is shown an approved method of locating sliding V-blocks. The block is fitted on the sides to the slot at *C* and is held down by means of gibs at *D*. The block is operated by means of a screw at *E*. This is the best method of making a sliding V-block, but it is sometimes desirable to make the gib *D* in the form of a flat plate extending completely across

the V-block. Naturally these points may be varied to suit and do not affect the fundamental features of design. Another type of block is shown at *F*. There may be cases when a block of this kind has advantages but in general it is expensive to make and has no practical advantage over the design shown at *B*. The plate *G* is expensive and difficult to fit.

The method of fitting a slide as shown at *H* is not to be commended as it is much more difficult and expensive than the design shown at *B*. We have seen V-blocks made in this way but have not approved of the design. It is usually considered good

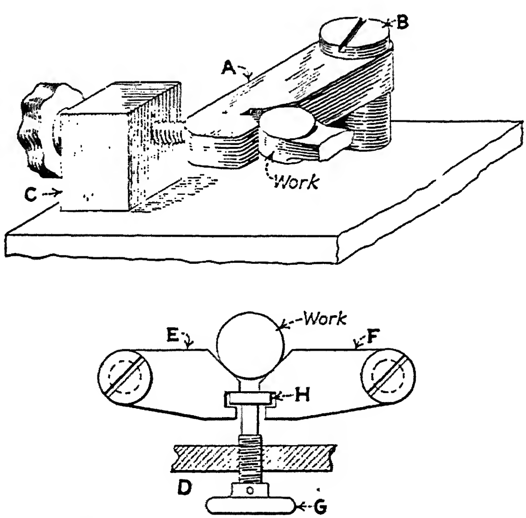


Fig. 51. Swinging V-block Design

practice to keep a design as simple as possible so as to avoid unnecessary machining and fitting.

In Fig. 51 is shown at *A* a type of swinging V-block which is quite useful on small work. Blocks of this kind are useful where the work is located by a central stud on the jig. The work shown would be difficult to locate in a regular sliding V-block. Blocks of this kind can be made up in quantities for small work and to a certain extent standardized so that they can be used by simply drilling and tapping a hole for the screw shown at *B* and applying the block *C* which carries the backing-up screw.

Another type of swinging V-block is shown at *D*. The V-block is made in two parts, *E* and *F*, controlled and adjusted by means of the thumbscrew *G*. The thumbscrew has a shoulder at *H* which engages with two supports on the swinging members. This type is used to a considerable extent by a large manufacturer in this country.

Leaf Jigs.—In the design of leaf jigs there are many points to be considered. In the example shown in Fig. 52 the jig *A*

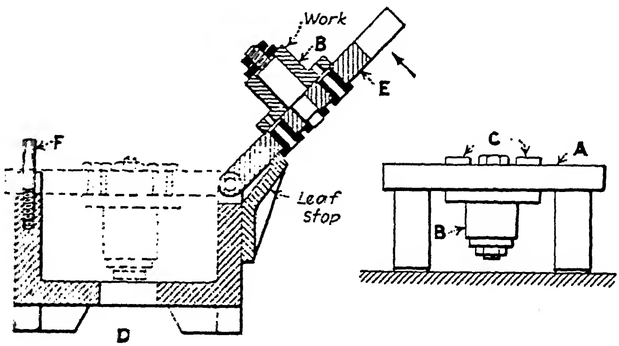


Fig. 52. Leaf Jig of Simple Design

was designed for holding the work *B*, while being drilled through the portions indicated at *C*. The work is fastened into the jig in one position, after which the jig is turned over until it assumes the position shown, in which position the drilling is done. There is no particular objection to this type of jig and it is in common use in many factories. However, a leaf jig design is shown at *D* for comparison. The leaf *E* is swung back against the leaf stop indicated while the work *B* is being loaded on to the stud. The leaf is then swung down into position carrying the work with it until it takes the location shown by the dotted lines. A quarter-turn screw *F* is used to locate the leaf in position. The advantages of this type over the one at *A* are that it is much more convenient to operate and if a multiple drill-head is used, it can be clamped firmly to the correct location on the table.

Leaf Construction.—In the construction of jig leaves the hinge is an important factor. Several methods are in vogue. There is a straight pin such as that shown at *A* in the upper

part of Fig. 53. In this construction it is considered good practice to make the pin so that it will be a drive fit in the leaf *B* and a running fit on the two end bearings. Probably the best construction obtained is by making the pin a standard taper like that shown at *C*. When this construction is used the adjustment for wear can be made very easily and any amount of freedom can be made in the leaf by simply giving an additional turn to the taper reamer.

It is sometimes desirable to make a leaf like that shown at *D*

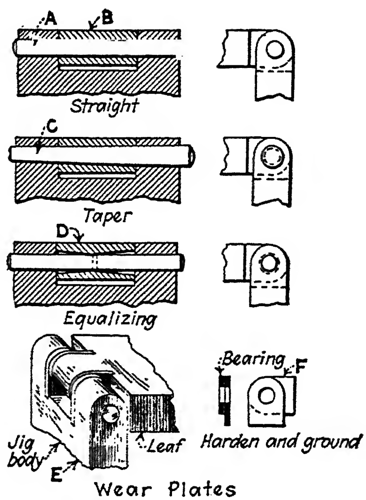


Fig. 53. Jig Leaf Construction

in order to obtain a slightly equalized action on the leaf when it is used for clamping or for some other purpose. In the construction of jigs which are to be used for thousands of pieces, it is advisable to make proper provision for wear in the leaf in order to preserve the accuracy. A construction such as that shown at *E* is excellent and is in use by a number of manufacturers. The wear plates shown at *F* are hardened and set into both the leaf and the jig body. It will be seen that they can be readily replaced when worn.

Clamps in the Leaf.—In connection with leaf construction we must also consider the instances when clamping action is applied through the leaf. There is an important point which should always be thought of when clamps are to be inserted in

a jig leaf, and that is that the leaf must be made heavy enough so that it will not buckle when the pressure is applied. In Fig. 54 several types of clamps which can be applied to the leaf of a jig are shown. The leaf *A* should be made heavy enough to take the pressure of the screw *B* so that it will not tend to buckle and take the position indicated by the dotted lines, as this would make the bushing *C* out of alignment with the work. Attention should also be paid to the position of the screw *B* in

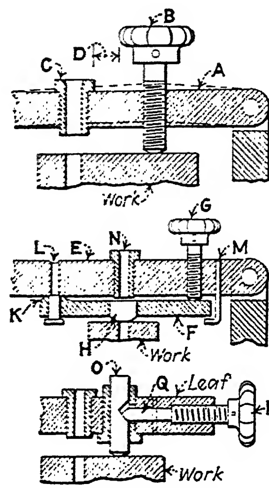


Fig. 54. Clamps in Jig Leaves

relation to the bushing *C*. The amount of space required at *D* will be dependent upon the general condition and size of the jig.

Another method of clamping through the leaf of a jig is shown at *E*. Pressure is applied through the clamp *F* by means of the screw *G* so that the ball-portion *H* comes in contact with the work as indicated. One end of the clamp is rounded at *K* where it bears against the leaf. It is prevented from falling out of the leaf by the pin at *L* and the guard pin *M*. This construction was used in order to allow free use of the bushing *N*, and at the same time clamp very close to it. It is evident that a hole in the clamp is necessary as indicated.

A very useful type of leaf clamp for small work is indicated at *O*. It is a type that is used preferably on finished work because its action is limited. The movement of the pin *O* is con-

trolled by the screw *P* acting on the angular cut in the pin through the plug *Q,* also cut to an angle on the end which engages with the cut in the pin.

There are some cases where the clamp is used in a leaf when the leaf does not carry any bushings. Referring to Fig. 55. the sketch at *A* shows a leaf of this sort having a rocking clamp *B* pivoted on the leaf. There are no bushings in the leaf and it is used principally for clamping. The clamp pressure is applied through the eye-bolt and hand knob *C* and *D.* The end of the leaf must be slotted so that the bolt can be swung out of

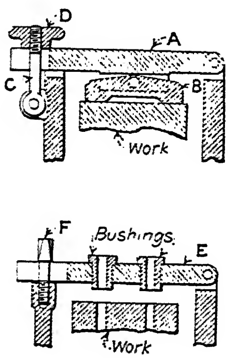


Fig. 55. Leaf Construction

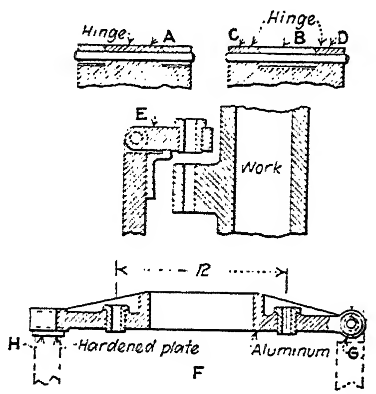


Fig. 56. Details of Jig Leaves

place in order to lift the leaf. This form of construction is very common and will be found useful in many cases.

When a leaf contains several bushings as at *E* the form of construction shown is commonly used. The end of the leaf is so slotted that the quarter-turn screw *F* passes through it when the leaf is lifted. When it is locked in position the head of the thumbscrew binds it firmly in place.

In Fig. 56 several kinds of leaves are shown. Two methods of making a hinge are indicated at *A* and *B*. In the case *A* the hinge swings at *A* and therefore has a short bearing, while in the other case the hinge hangs from the points *C* and *D*, which are much further apart so that greater accuracy is assured.

A leaf like that shown at *E* is sometimes useful in jig construction when it is necessary to place a bushing close to the

work and at the same time get it out of the way while the work is being removed. It is a good idea to provide some means of clamping the leaf while drilling. A quarter-turn screw or some other approved method can be used.

It is often necessary to lighten a large jig in order to expedite the handling of it. Sometimes it is advisable to make a leaf out of aluminum as shown at *F*. It is a good idea to provide bushings at the hinge point *G* and hardened plates at the end *H* in order to avoid having the wear on the soft metal.

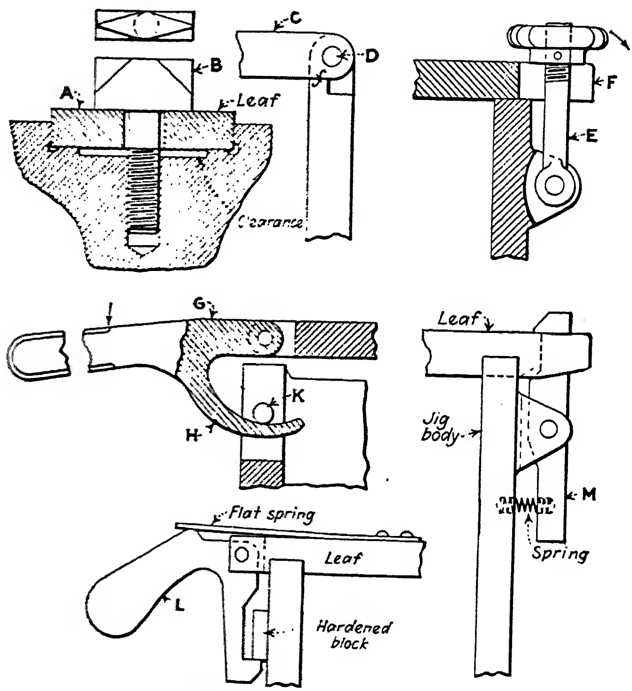


Fig. 57. Leaf Locking

Leaf Locking.—Jig leaves may be locked in a variety of ways, several of which are shown in Fig. 57. The leaf *A* is fastened by means of a quarter-turn screw *B*, the end of the leaf being slotted. Wear plates at the bearing points should be provided if the jig is to be used for a great number of pieces. Sketch *C* shows provision to simplify the toolmaker's work in putting in the pin *D* by leaving the finished support *f* from

which to locate the jig leaf while drilling the pin hole. This support can be machined when planing up the jig. An eye-bolt lock for a jig leaf is shown at *E*. When such a lock is used the end of the leaf should be rounded off at *F* in order to facilitate the opening. The cam lever fastening shown at *G* can be used to advantage in many cases for fastening the leaf in position. Care must be taken to make sure that the radius *H* is not too small to prevent the proper locking on the pin *K*. As a general thing tool designing departments have a set of standard cam levers which give the important dimensions. Two other types of leaf lock levers are shown at *L* and *M*. Speaking generally the writers do not favor these forms of construction. It must be admitted, however, that they are in use in a number

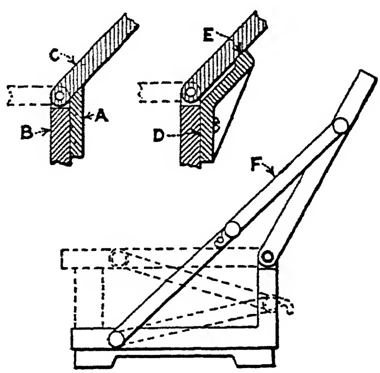


Fig. 58. Leaf Supports

of factories with more or less success. The principal objection to their use is the fact that there is very little adjustment for wear and they are therefore likely to become inaccurate after they have been used a short time.

Leaf Stops.—When a jig is being used it is important to provide a rest for the leaf when it is thrown back in loading or unloading the jig. If some provision is not made there is a chance that the operator may throw the leaf over and break or strain it. Several types of leaf stops are shown in Fig. 58. The one indicated at *A* is a simple type which is fastened to the wall of the jig *B* so that the leaf, when swung up, comes against it at *C*. Another type, shown at *D*, is somewhat similar, but very

much better, because the point of leverage E is farther away from the hinge.

Another type of leaf support is shown at F. The leaf is held up by means of an arrangement similar to a trunk lid support. This construction is "trappy" and possesses no particular advantages. There may be cases, however, in a very large jig where a similar application may be found useful.

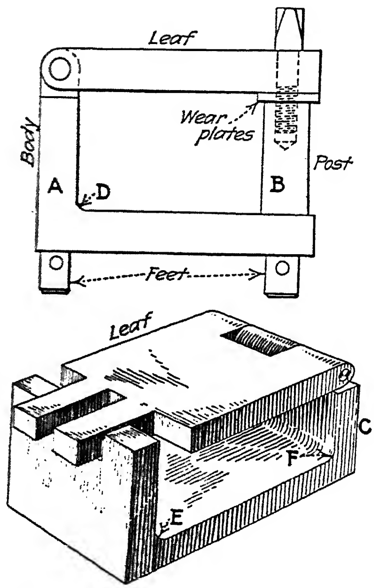


Fig. 59. Standard Angle and Channel Iron Jig Bodies

Standard Jigs and Components.—There are many parts of jigs and fixtures in common use that can be standardized either to obtain uniform design or to enable a factory to make them up in quantities. There are some parts that are seldom used but the general design and proportions of these are so well established that drawings can be made of various sizes to cover practically all conditions. There are also many accessories such as thumbscrews, hand knobs, ejectors, jig bodies and jig leaves, which can be made in certain sizes and carried in stock so that the toolmaker can use them whenever they are shown on a tool drawing without having to make up each one as he requires it. In addition to the parts mentioned it is possible to standardize

bushings so that they also can be made up in quantities. However, this is not frequently done as there are so many sizes to take into consideration.

Standard Jig Bodies.—There are two varieties of standard jig bodies, the angle-iron form and the channel-iron form; of

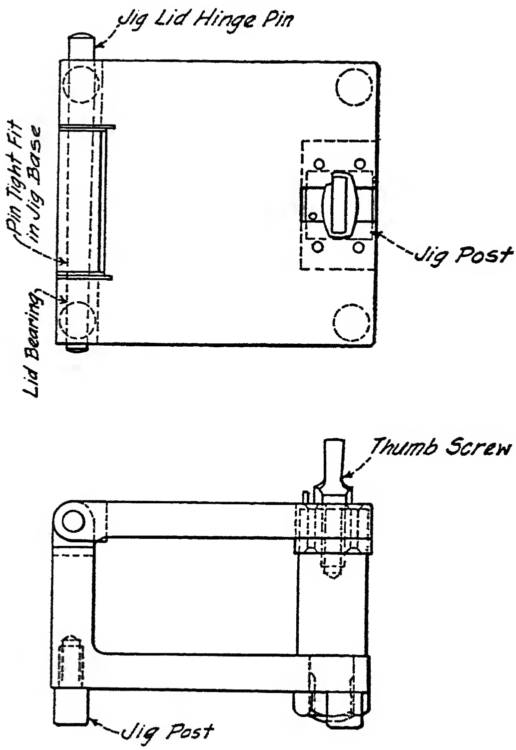


Fig. 60. Standard Type Jig Body

these varieties the angle-iron form is the more common and is frequently found both in steel and cast iron. The channel-iron jig body is less common except in certain classes of work where a great many parts of small and comparatively uniform sizes are to be jigged. Referring to Fig. 59 a standard steel angle-iron jig body is shown at *A*. The usefulness of such a jig body is very apparent and it has the advantage of being made up cheaply for a variety of usages. For small parts requiring leaf jigs, many combinations can be made with angle irons of this

variety. It is easily possible to build up a post like that shown at *B* and fit a leaf with thumbscrew and wear plates, as indicated, to suit a great number of conditions. The jig feet can be screwed into place as shown and can be put in wherever they are needed. Another advantage of this type of jig is that the angle iron can be made in a long strip and planed up accurately and then cut up into sections which may or may not be standardized for width according to the requirements. A great many factories carry angle iron in stock ready for use when needed.

On certain classes of work a channel-iron body may be found a great advantage. For example, the channel-iron body *C* may be made up in a number of sizes and may be standardized for

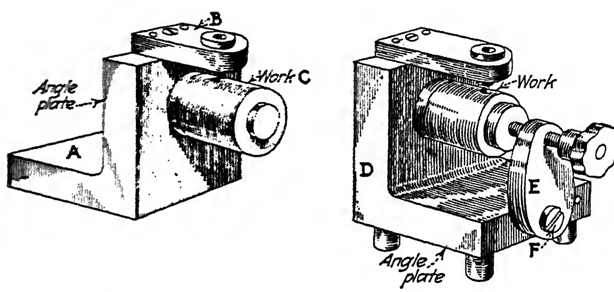


Fig. 61. Angle Iron Jigs Made of Cast Iron

width, depth and length. Assuming that three or four sizes are carried in stock it is evident that a leaf may be fitted in; a V-block or locating pin inserted; clamps put on; or other appliances fitted to suit a great number of cases. In the standardization of jig bodies the manufacturer must be governed by the relative size of the components in his product.

It may be well to state in passing that it is advisable to provide good fillets on all angle-iron and channel-iron castings or forgings as shown at *D, E* and *F*, to make the sections as strong and serviceable as possible. If it is necessary at any time to fit blocks or other parts around the fillets, it is advisable to chamfer the block rather than to cut out the fillet, so as not to weaken the fixture.

A standard type of jig body without dimensions is illustrated in Fig. 60. This is a very good design which can be used on many classes of small work. Dimensions can be given on the various

parts so that the tool designer can obtain a better understanding of the requirements in designing a standard jig body.

The utility of an angle-iron jig is indicated in Fig. 61. The angle irons are of cast iron. There is shown at *A* an angle plate made into a simple jig by applying the bushing plate *B* and a locating stud on which the work *C* is held. This is a very simple form of jig in which the work is held in place by hand while drilling.

Another application of the angle-iron jig is shown at *D*. A bushing of similar form is to be drilled in such quantities that

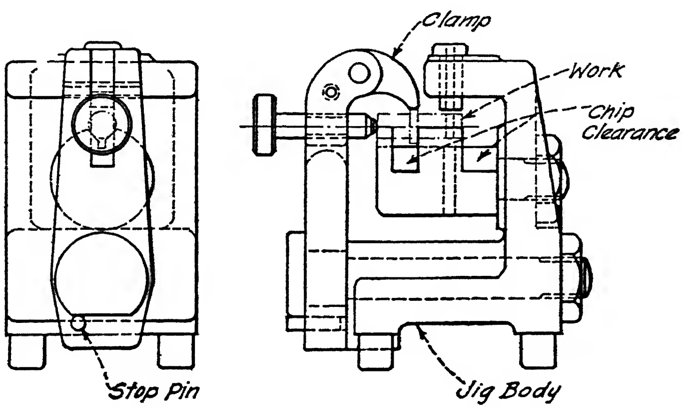


Fig. 62. Well Designed Jig with Rocking Clamp

it is advisable to provide a means of clamping the work. The clamp *E* is pivoted at *F* so that it will swing out of the way when not in use, thus allowing the work to be removed from the stud without difficulty. Other applications of angle-iron jigs will be mentioned in a subsequent article.

We have made mention of the importance of proportioning a rocking clamp so that the clamping points are about the same distance from the center. An example which illustrates the application of a clamp of this sort is shown in Fig. 62. The body of this jig is made of cast iron and the clamp is of such a nature that it swings free of the work on a swiveling arm. In this application the work is held in a V-block and the clamp holds it firmly against the shoulder and carries it down into the block at the same time.

Advantages of Standard Jigs.—Another advantage of a standard size and form of jig is in the location of the jig when in use on the drilling machine. Let us assume that a number of different jigs are used from time to time and we know that it takes a little time for the operator to arrange the machine so that each jig will be conveniently handled. By the use of standard jigs it is possible to clamp or screw down guides, as indicated at *A* and *B* in Fig. 63, so that jigs of a standard size

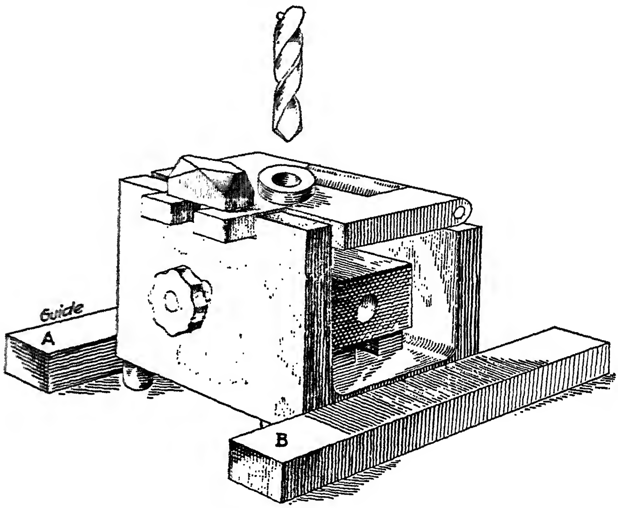


Fig. 63. Standard Jig Used Between Guides

can be readily slipped between the guides when changing from one part to another. In the standardization of jigs other applications will be found which will prove profitable in the actual processes of manufacture.

The same idea of using guides can be applied on large cast-iron jigs providing the sides of the jig are finished so they will pass between the guides. In progressive drilling an arrangement of this sort will be found to be a great advantage.

In taking up the various components which are used in built-up jigs we must not forget the jig post and the frequently used quarter-turn screw. Several examples are shown in Fig. 64. Example *A* is not generally considered good practice because there is no locating provision made to take care of abuse or wear in the leaf. The quarter-turn screw *B* does not assist in locating

the leaf, and the accuracy is entirely dependent upon the hinge construction.

Jig Posts and Thumbscrews.—It is much better to make a jig post as shown at *C* and to allow the leaf to locate on the sides *D* and *E*. Provision for wear may be made as indicated at *F*, in which the same type of jig post is used as that shown at *C*, but provided with wear plates of hardened steel at *G* and *H* so that the accuracy of the leaf fitting is assured. The post can be

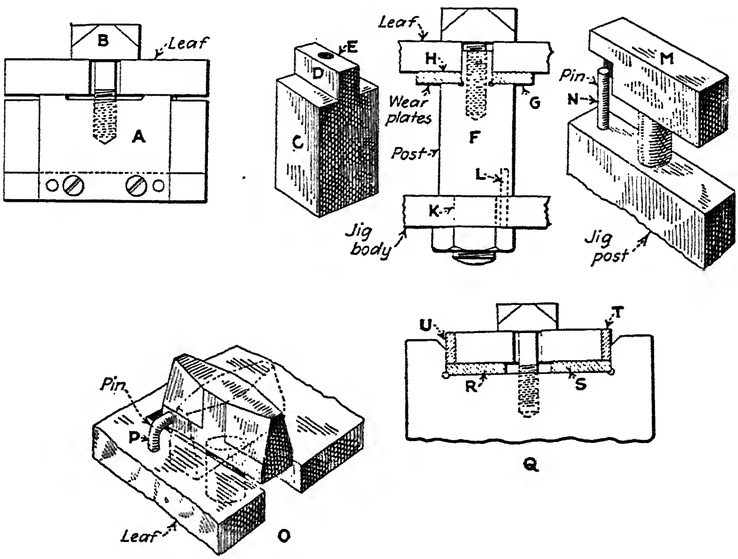


Fig. 64. Jig Posts and Quarter Turn Screws

turned and threaded at its lower end as indicated at *K* and a suitable dowel provided at *L* to make location positive.

A type of jig post sometimes used, shown at *Q*, can readily be made so that it will screw onto the body and it can be furnished with wear plates at *R* and *S* if desired. In addition the leaf can be provided on the sides at *T* and *U* with plates that can be hardened and ground to an accurate fit.

Quarter-turn screws are frequently used in leaf jigs; several varieties are shown in the figure. When screws of this kind are used it is necessary to turn them so that they are in alignment with the slot in the leaf when loading or unloading the jig. A refinement which makes it possible for the operator to turn the

screw the right amount every time is shown at *M*. The underside of the thumbscrew is cut away and the pin *N* acts as a stop for the screw. Another method which gives the same result is

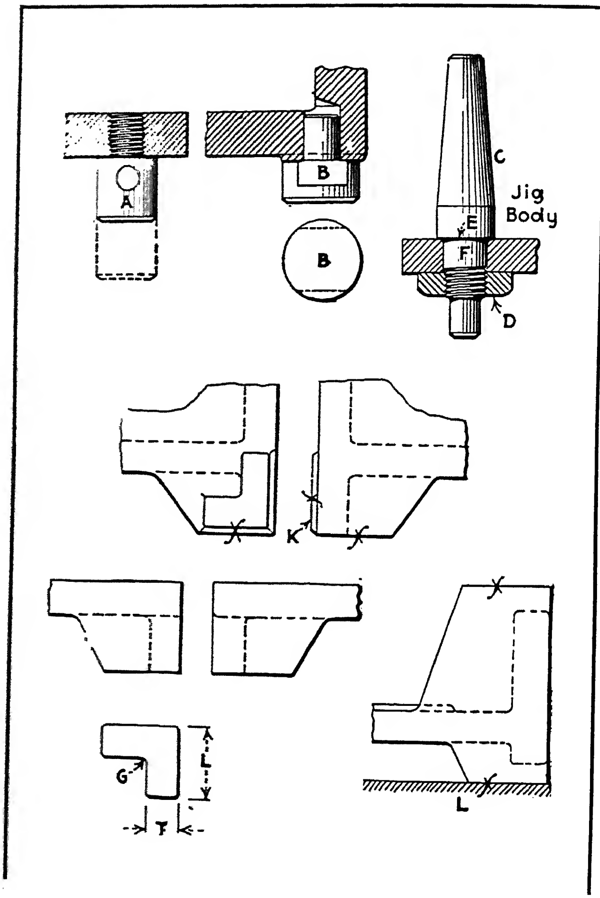


Fig. 65. Examples of Jig Feet

shown at *O* where the stop pin *P* is fitted to the leaf instead of in the jig post.

Jig Feet.—There are several things to be considered in the design of jig feet. They should be made long enough so that there will be room to take care of an accumulation of chips under the jig body, yet not long enough to be fragile. They

may be screwed to the jig body, a hole being provided, as indicated at *A*, Fig. 65, in which a pin can be placed to assist in the operation. Occasionally it is desirable to force in the jig feet, instead of screwing them in place, and when this is done it is

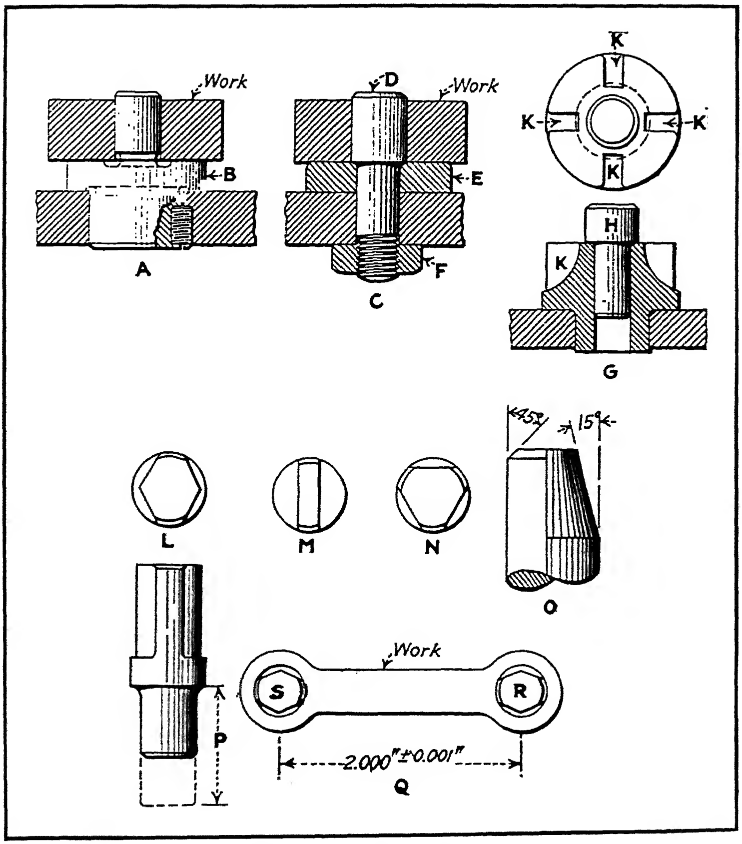


Fig. 66. Locating Plugs

advisable to use a construction similar to that shown at *B* in which flats are provided to assist in assembling.

A very excellent method of fastening jig feet in place is shown at *C*, a system frequently used when a jig has to be turned or if feet are provided on each side. The nut *D* can be used to draw the foot tightly into position and its location and accuracy can be assured by the squareness of the face *E* and the accuracy

of the fit on the shank of the foot at *F*. It is advisable to provide means for locking the nut, consequently the thread on the shank should be of fine pitch.

When jig feet are of cast iron it is well to make the thickness *T* of the foot equal to the wall of the jig and the length *L* about two and one-half times the thickness.

It is well to make jig feet for cast-iron jigs in the form of an angle as indicated at *G*. Attention should be paid to the proportions of this angle, if the jig is a small one, in order that it may be large enough to overlap any hole in the drilling machine table. A construction such as that shown at *H* is recommended when work is to be drilled from two sides of a cast-iron jig; it will be noted that a pad is placed at *K* at right angles to the jig foot, yet on this side of the jig the foot is not built up high because it would make an awkward construction and one that might very easily be broken. When jig feet come opposite each other it is well to make the design similar to that shown at *L*, a construction that is strong and that gives ample clearance for chips.

Locating Plugs.—Several designs of locating plugs are shown in Fig. 66. In sketch *A* the plug *B* is made of one piece of steel, a construction requiring considerable labor. It is much better to use a construction similar to that shown at *C* in which the plug *D* is used in connection wtih a hardened and ground washer *E*. The locating plug is drawn up tightly by means of the nut at *F*.

Care must be taken when a piece of work rests on a flat surface to furnish little space for dirt and chips to accumulate. In sketch *G* a plug is shown at *H* and the work rests on *K*, cut out in four places to give less bearing surface and to provide clearance for the drill after it has run through the work. The slots could be made somewhat larger and thus leave less chance for dirt and chips to accumulate. In making up locating plugs for use in a round hole it is advisable to relieve them so that they will not completely fill the hole. They can be relieved as shown at *L*, *M* or *N*, depending upon circumstances. The methods shown at *L* and *N* are much to be preferred to that shown at *M*. The latter tends to weaken the plug so that it is easily broken. All plugs that are made a drive fit in a jig or fixture must have sufficient stock that they will not loosen easily

when in use. The length of drive should be from two and one-half to three times the diameter as shown at *P*.

In chamfering the top of a plug which is to receive a piece of work the angle of the chamfer should be as long as can conveniently be made. It can be from 45 to 15 deg. on the side, but it is much better to approach the 15-deg. angle rather than the 45-deg. angle, as the work will assemble much more easily and will not tend to "cock." A diagram showing a method used in locating a piece of work on two plugs is shown at Q. This is a connecting rod in which the holes at the ends are held within limits of ±0.001 in. The two plugs shown are relieved but not correctly. The plug *R* can remain as it is, but

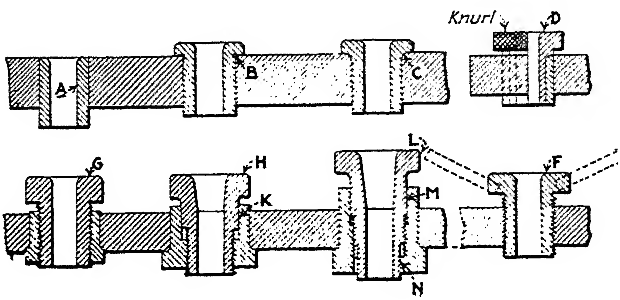


Fig. 67. Types of Bushings

that at *S* should be turned around 90 deg. in order to allow for possible variations in the work.

Types of Bushings.—Fig. 67 shows a number of types of bushings used in jig construction. Bushing *A*, a common type having no head, is used almost exclusively by some factories, but the majority prefer bushings with heads and we believe this type to be better in the majority of cases on account of the abuse to which bushings are subject. The bushing shown at *B* is undercut at the shoulder. This is not good practice; it is much better to round the bushing slightly as shown at *C* and chamfer the casting a trifle as in this way a bushing is obtained that is stronger and is less likely to crack or break either in use or when hardening.

In the design of slip bushings the knurled form shown at *D* is frequently used. It is well to state at this point that all slip

bushings should be provided with hardened liners as indicated at *E*. A screw bushing, as shown at *F*, is very bad and should never be used. When it is necessary to make bushings so that they will screw into a jig a hardened liner should be provided as indicated at *G*. The head of the liner bushing is on the inside of the jig so that when pressure is exerted on the bushing there will be no tendency to force out the liner.

Screw bushings are used in some cases where a clamping action is needed on the work at the point where the bushing is used. If it is found that no other means of clamping can be used, a much better form of construction is that shown at *H* in Fig. 67. The accuracy of location in the slip-bushing is assured by the cylindrical bearing at *K* and the threaded portion is made a loose fit. An additional refinement is found in bushing *L* which has a cylindrical bearing at *M* and *N* and a thread in the middle. This type insures as high a degree of accuracy as is possible for screw bushings.

Provision should always be made to insert a pin in bushings of this kind in order to facilitate removal. The matter of spring in the jig leaf must also be considered when a screw bushing is used, as it generally is, for clamping. The jig leaf should be reënforced sufficiently to take care of the strain incurred.

Bushing Design and Proportion.—Various methods of making bushings, of which some are good and some bad, are shown in Fig. 68. The bushing shown at *A* is too short and does not give proper alignment for the drill, so that it is likely to cause inaccuracy as indicated at *B*. It is well to make a bushing from two to three times the length of the drill diameter if possible so that it has an appearance similar to that shown at *C*. So doing keeps the drill in good alignment and does not tend to produce angular holes. A bushing should have sufficient stock in contact with the hole into which it is pressed that it will not tend to loosen when in use. The bushing shown at *D* has only about one diameter in contact with the hole into which it is pressed whereas the bushing *C* has over two diameters. It is sometimes possible to use a construction like that shown at *E* where the jig wall is thin, and it is not possible to obtain great depth for the bushing. A screw such as that shown at *F* can be used to hold the bushing in position.

In regard to the relieving of the inside of the bushing, the

form shown at *G* is tapered for a part of its length, a construction much better than if counterbored as shown at *H* because in the latter case the drill lip may strike the edge of the counterbore and cause trouble. Jig bushings are usually rounded to facilitate the entrance of the drill as indicated at *K*. It is ad-

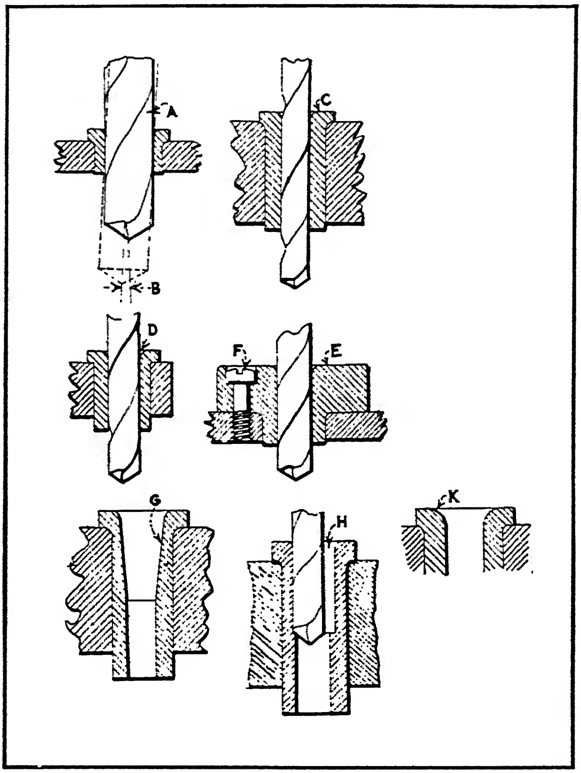


Fig. 68. Bushing Design and Proportions

visable to use a large radius in the mouth of the bushing wherever possible. Data relative to the distance between the work and the bushing have been given in a previous chapter.

Methods of Holding Slip Bushings.—Slip bushings are used in many cases where it is necessary to drill and ream the same hole in the same jig. The first bushing is made to the drill size and the second bushing to the reamer size. When slip-bushings are used provision must be made to prevent the bushing from

pulling out of the jig when the drill is being removed. Several varieties of locks or clamps are shown in Fig. 69. There is shown at *A* a very common type which has a pin *B* with a shoulder which locks the bushing in place, a type used in the majority

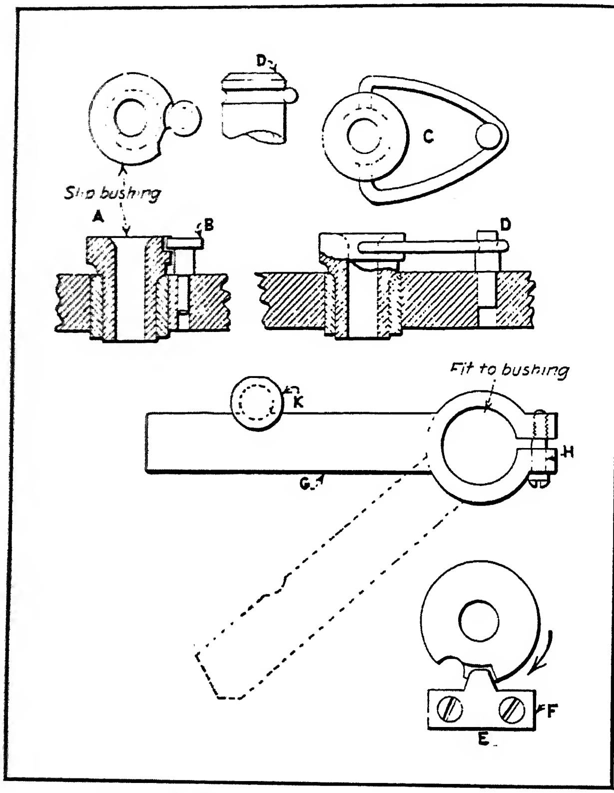


Fig. 69. Methods of Holding Slip-bushings

of shops. A bail-bushing is indicated at *C*. There are advantages to this type of bushing for large work in that it is conveniently removed, as the bail acts as a handle and the bushing is locked in position by snapping the bail down over the pin at *D*. Another form of lock for a slip bushing is shown at *E*, embodying the same principle as that used at *B*. Instead of using a pin for locking, a steel block as shown at *F* is screwed to the jig body. Another form of clamp for holding a slip bush-

ing is shown at *G*. The lever is clamped around the bushing by means of the pinch-binder at *H* and the bushing is prevented from pulling out of the jig by means of the retaining pin *K* which is shouldered so that the lever passes under it. The action of the drill tends to throw the lever against the pin *K*. In removing the bushing the lever takes the position shown by the dotted line.

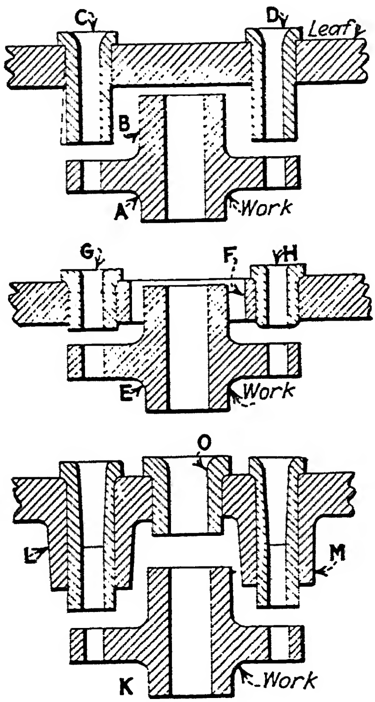


Fig. 70. Locating of Bushings

Location of Bushings.—The shape of the work to be drilled influences to some extent the location of the bushings. There are cases where a piece of work is so designed that it is difficult to place the bushings so that accuracy will be assured in the drilling operation. In the first chapter of this book the effect of design on the machining process was commented upon to quite an extent, and it was pointed out that the design of the work is an important factor which influences the efficiency of jigs and fixtures. There are some tool designers who are very

harsh in their criticism of the pieces for which they are called upon to design tools and are continually suggesting changes in their design. Changes in design are costly, especially if they cause the changing of expensive patterns, and should not be made unless there is something worth while to be gained.

However, it has been pointed out that there are numerous instances when a change in design would result very profitably to the manufacturer.

A piece of work is shown at *A*, Fig. 70, having an extended hub *B*. The inexperienced designer would be very apt to locate his bushings as shown at *C* and *D*, without sufficient support in the jig body. Either of two methods can be used to avoid the difficulty. In the method indicated at *E* the jig body is cut out at *F* to allow the hub to pass up into it so that the bushings *G* and *H* can be so made that they will have sufficient contact with the jig body. Another method is indicated at *K*, where the body of the jig is carried down in the form of bosses *L* and *M* to give stock for the bushings. Provision is made for drilling the center hole through the bushing *O*.

Standard Knobs and Thumbscrews.—The ability of the tool designer is frequently shown in small ways such as the application of thumbscrews or knobs to operate various moving parts in the jig. It is well to consider the fact that the workman who handles a jig or fixture has to use his hands all day long. Speaking generally, a knob or thumbscrew should be so arranged that the operator can use it without "skinning his knuckles" on some surrounding part of the jig. The form of the knob should be such that it will not make an operator's fingers sore.

It is advisable to avoid the use of knurled screws as far as possible, because they tend to make an operator's fingers tender if used frequently. The knob shown at *A*, Fig. 71, can be made with as many points as desired and it can be of steel or cast iron. If it is standardized, a number of sizes can be made up and carried in stock to suit various conditions. The hole may be drilled so that it can be readily fitted to standard sizes of screws or studs, as shown at *B*. A pin *C* is generally used to fasten the knob in position.

Another type of knob, shown at *D*, can be used to advantage in numerous cases. The knob itself may have as many notches as seem desirable, this being a matter for individual decision.

In this case the knob is made with a long hub tapped out at *E* so that it can be used to pull up on a stud or down on a clamp; in fact it can be used in a number of ways which will suggest themselves to the tool designer. These knobs also can be made up in several sizes and carried in stock. A very common method of providing a means of adjusting a screw is shown at *F*, where a pin *G* is driven into the end of the screw to act as a handle.

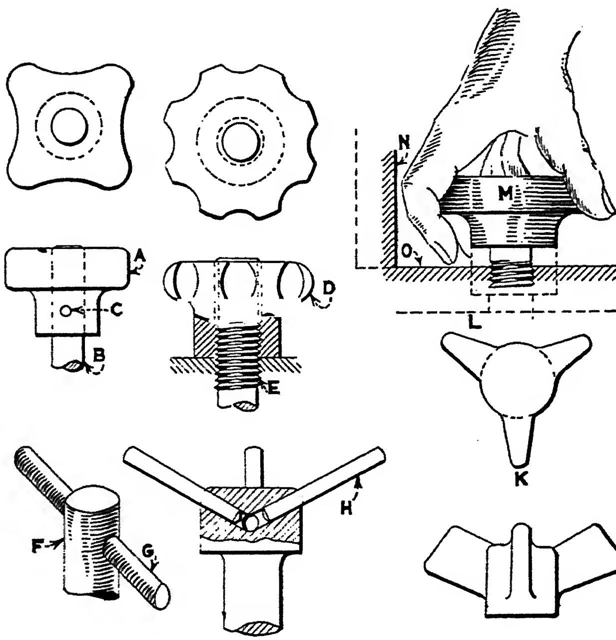


Fig. 71. Standard Knobs and Thumbscrews

In the writer's opinion this construction should be used very seldom, except when very light pressure is to be applied. The objection to this method is that it is hard on an operator's fingers and that he is frequently tempted to use a wrench in order to tighten the screw; as a result the pins very soon become bent and practically useless.

A general form of pin knob is shown at *H* in which the pins are four in number and are set in at an angle. Even in this case however there are objections to the form used for much the same reasons as previously stated.

A very excellent form of knob or thumbscrew is shown at *K*.

This form has become a standard in many shops and is excellent both from the viewpoint of economy and convenience of operation. The knob has three points which accommodate themselves to the operator's fingers and do not make them sore. It is a form that can be used as a nut when drilled and tapped, or in a manner similar to that shown at *A*.

A diagram which indicates the importance of clearance for the operator's fingers is shown at *L*. The knob *M* has been so placed that there is very little clearance for the workman's fingers between the screws and the walls of the jig *N* and *O*. The amount of clearance necessary is shown by the dotted lines. It is a very good idea for a tool designer to imagine that he is

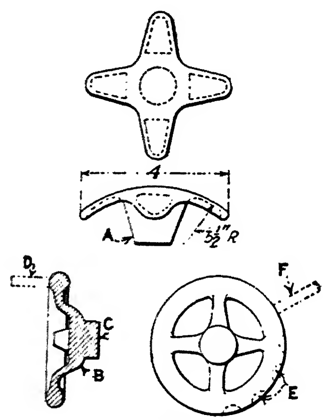


Fig. 72. Handwheels and Large Hand Knobs

operating the jig himself, making sure that his finger clearance is ample. At the same time he must remember that the shop man's hands are somewhat larger than his own and he should therefore make considerable allowance for finger clearance. The writer has frequently seen jigs, considered good by the drafting room, that caused the operator untold trouble, due to improper provision for his fingers.

It should be remembered by the tool designer that the amount of pressure to be exerted influences the size of the knob to be used and it is sometimes found desirable to use a knurled screw in order to prevent the application of pressure enough to distort the work or spring it out of its true position.

Handwheels and Large Knobs.—On large fixtures it is frequently necessary to use handwheels or large knobs in order to provide pressure sufficient to operate the mechanism. The beginner is very apt to be "stingy" in the details of his design whereas the experienced designer is "generous" and makes a "comfortable" jig which can be used with satisfaction by the operator.

A form of hand knob which has found a great deal of favor with manufacturers in general is shown at *A* in Fig. 72. This

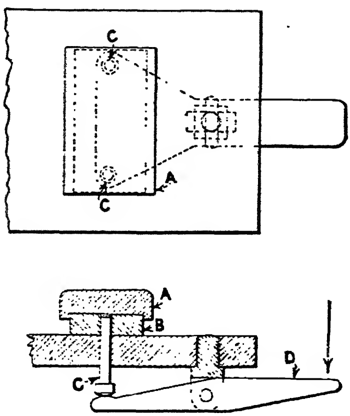


Fig. 73. Simple Ejector for Drill Jig

form of knob is usually made up in one or two sizes, the example shown being the 4-in. size. A knob of this kind is used only on large fixtures and jigs where considerable pressure is needed. It is generally made of cast iron and the hub is left solid so that it can be drilled or tapped to suit particular conditions. The advantage of this knob is that it fits the palm of the hand and the fingers can go down between the points which enables the operator to get a good grip.

On large fixtures it is often desirable to use handwheels such as that shown at *B*. Handwheels of various sizes can be purchased cheaply and can be drilled or tapped in the hub *C* to suit any particular job. It is also possible to provide the wheel with a handle, as shown by the dotted lines at *D*, if desirable.

There may be cases where it is an advantage to notch a handwheel as shown by the dotted lines at *E* so that an operator can

get a little better grip. A handle can be put in as indicated by the dotted lines at *F* to provide more leverage.

Ejectors for Drill Jigs.—There are many cases when it is essential to provide a means for removal of a piece of work from a jig or a fixture. It is not good practice to make up a jig in such form that the operator must use a hammer or screwdriver to get the work out after it has been machined. A simple form of ejector may be used, such as shown in Fig. 73. The

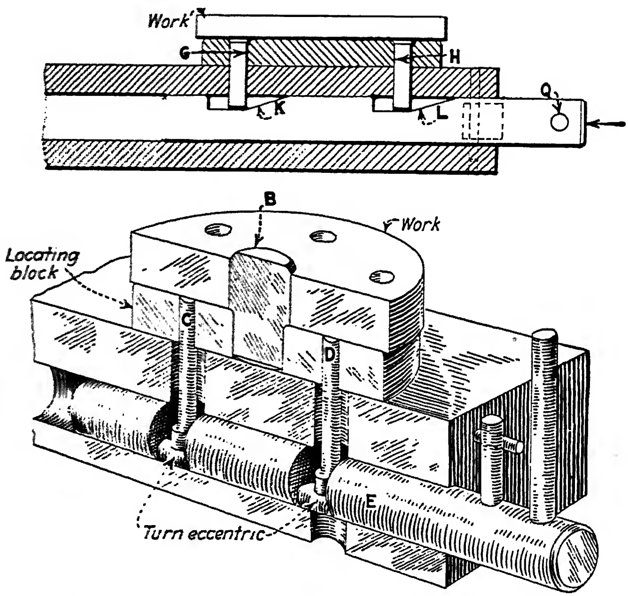


Fig. 74. Ejectors Operated by Eccentric and Wedges

work *A* has been placed on the locater *B* which it fits snugly. To remove the work the operator would be obliged to use a screwdriver to pry it off from the locating plug *B* unless provision was made for ejection. It is a very easy matter to insert the pins as shown at *C* and to operate them by means of the lever *D*.

There are many cases where a somewhat simpler form of ejector can be used. The pins *C* could be held by a retainer and the lever *D* left off entirely. The operator could provide a wooden block on his drilling machine table and operate the ejector by striking the pins on it.

There are occasional cases where the removal of a piece of work from the jig requires that considerable attention be paid to the method of removal. A case of this kind is shown in Fig. 74 in which the work *A* is located on a central stud *B* which it fits closely. Ejectors are formed in this instance by two pins *C* and *D* which extend through the locating block as indicated and rest on eccentric portions of the shaft *E*. When the lever *F* is operated the eccentric causes the pins to rise and push the work from the plug. Another method of operating a similar mechanism is shown in the upper part of the figure. The ejector pins *G* and *H* are operated by means of the angular surfaces *K* and *L* on the rod *P*. A pin or hand knob can be provided at *Q* or as conditions require.

Speaking generally, the use of ejectors would be required on any piece of work that could not be easily removed by hand. It is advisable to consider the conditions and the necessity for ejectors when designing any jigs in which the location is by means of finished surfaces, pins, or plugs. When ejectors are used the pressure must be distributed in such a way that it will not cause a "cramp" or "cock" in the work.

CHAPTER IV

OPEN AND CLOSED JIGS

Templet Jigs—Plate Jigs—Open Jigs for a Shaft—Open Jig for a Pump Cover—Closed Jigs—Closed Jigs for Angular and Straight Holes—Locating and Assembling Jigs—An Example for Practice.

In the previous chapters we have taken up a number of points in connection with the design of drill jigs. We shall now apply

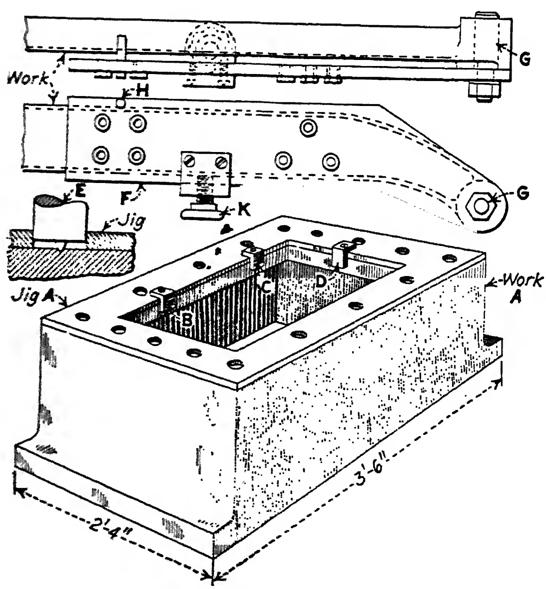


Fig. 75. Templet Jigs

some of the principles which have been described. It is not our intention to apply every principle or each mechanism which has been mentioned, but rather to give a few examples of jigs of

various types to illustrate the general procedure in jig construction. From the examples given the tool designer can note various features of importance and by careful study he can doubtless see other ways in which the same piece of work can be jigged. As a matter of fact the studious designer will find it to his advantage to consider each jig shown and endeavor to handle the work in as many different ways as he can, applying the principles which have been carefully explained in the preceding chapters.

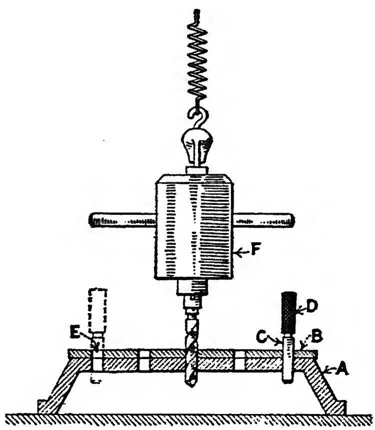


Fig. 76. Use of a Templet Jig with Locating Plug

As explained previously, the templet jig is the simplest form that can be made. In elementary form it is sometimes nothing more than a thin plate of steel with holes located to suit the condition. This plate is often set on the work and marked with a prick-punch or scriber. Templet jigs of this kind would be made up only in cases where there were a dozen or so pieces to be drilled and also when the location of the holes did not require very great accuracy.

Going a step further in the design of templet jigs let us consider the ones shown in Fig. 75. The work *A* is a cast-iron frame of large size; there are a number of holes to be drilled on the upper surface, and there are only a few pieces to be machined. In order to drill these cheaply and to have uniformity for the various pieces, the jig *A* is made up of sheet metal and is furnished with three locaters shown at *B*, *C* and *D*.

The templet is placed in the position shown and clamped in place by some convenient method, using the locaters to bring it into the correct position. The holes are then prick-punched with a punch similar to that shown at *E*, after which the templet is removed and the work drilled according to the locations marked.

Another templet jig is shown at *F* in which the work is an

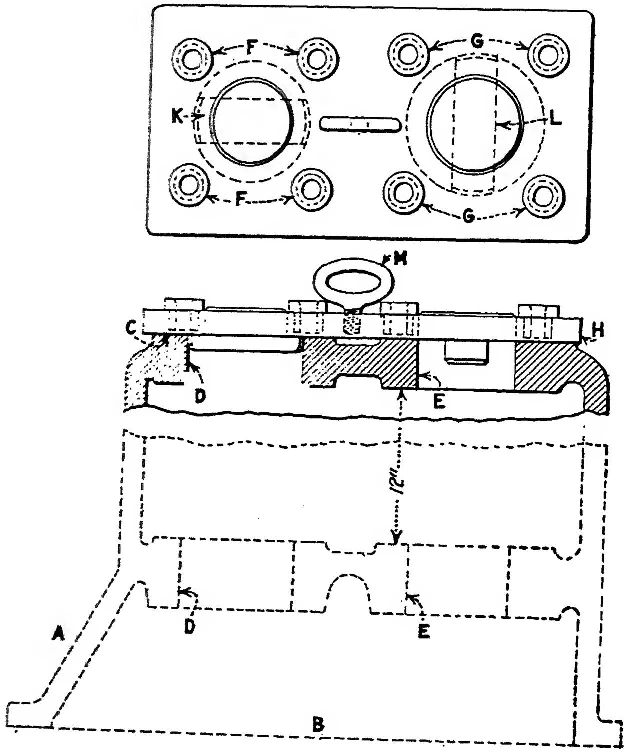


Fig. 77. Plate Jig for a Large Casting

automobile frame. The hole *G* in the front spring hanger is used as one locater for the jig and the pin *H* acts as the other stop against the side of the frame. This jig is a little more elaborate than the one previously shown as it is furnished with a thumbscrew at *K* to clamp it in position. Jigs of this kind may be furnished with bushings if desired, or they may be used with a prick-punch to locate the holes before drilling, as in the previous instance. It is evident that this type of jig could be

made much longer and carried farther along the frame to allow for the drilling of the other holes if necessary. A method of using a templet jig is shown in Fig. 76, the work being shown at *A* and the jig at *B*. Let us assume that the templet has been clamped to the work and that one hole has been drilled at *C*. A convenient method of making sure that the templet does not shift, is to use a plug like that shown at *D* in the first hole drilled. After this another hole can be drilled at some distance away as at *E* and a second plug inserted after which the remaining holes can be drilled without danger of disturbing the location of the templet. An electric drill, indicated at *F*, is convenient for work of this sort.

Plate Jigs.—There is a strong family resemblance between plate and templet jigs, yet there is a distinct difference, in that the plate jig is often used for high production while the templet jig is never used except when production is small. There are many cases where a large piece of work requires a few holes to be drilled accurately in relation to other holes which have been previously bored and reamed and it may frequently prove to be more economical to design a plate jig than to attempt to do the work in a very large jig in connection with other holes. An example of this kind is shown in Fig. 77, in which the work *A* is a large casting which has been machined on the base *B* and on the upper surface at *C* and in which the holes *D* and *E* have been bored and reamed. It would not be economical to make a large jig to drill the holes at *F* and *G*, especially as it is necessary to locate them in relation respectively to the reamed holes *D* and *E*. It will be found more economical to make up a plate such as that shown at *H*, which has bushings provided at *F* and *G* and which locates by means of the studs *K* and *L* in the reamed holes. It is evident that a large jig of this sort would need nothing to hold it in place as it would be quite heavy. Therefore a handle is provided at *M* by which to lift it off the work after the drilling has been done. Jigs of this kind are in common use in many factories.

In Fig. 78 is shown another application of a plate jig which, like that in the previous instance, is located by means of a stud *A* in the center hole of the work *B*. This stud is provided with a key at *C* in order that the location of the holes *D* may be in a given relation to the keyway. The location of the holes

D is such that it would be difficult to support the work properly unless particular provision were made. In order to assist in drilling, a support *E* is made up of cast iron so that the work rests on it. There are occasional cases where a support of this kind may be used in order to avoid designing an expensive jig.

Jig for a Dovetail Slide.—A simple plate jig, which will give very accurate results, is indicated in Fig. 79. The work *A* is

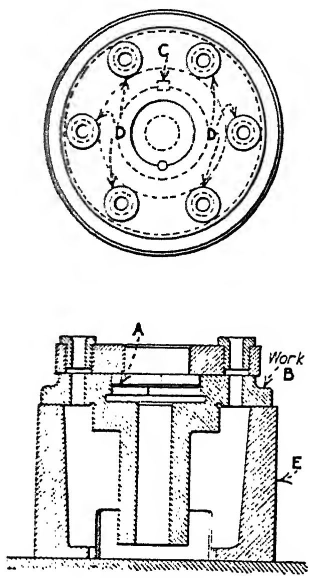


Fig. 78. Plate Jig with Accessory Support

a dovetail slide which has been finished all over and in which it is necessary to drill the four holes shown at *B*. These holes must be drilled in correct relation to the dovetail and it is therefore necessary to locate the plate jig in the dovetail slide as indicated. The jig is provided with a binder at *C*, operated by a thumbknob *D*. The binding member is so made that it fits a circular recess in the plate and it is evident that this forms an excellent clamp to hold the plate in position. The end location of the jig is obtained by means of the stop-screw shown at *E*.

Open Jigs.—In the design of open jigs the general construction of the work to be drilled must be first considered. As a general thing jigs of this kind are made for work which does

not have a great depth. Occasionally they are so arranged that the whole jig must be turned over and the drilling done from the side opposite that in which the piece is loaded. This usually necessitates drilling against the clamp and while not always objectionable, it is considered better practice to drill against a solid surface. In the example shown in Fig. 80 the piece of work *A* has been previously reamed at *B* and has been milled

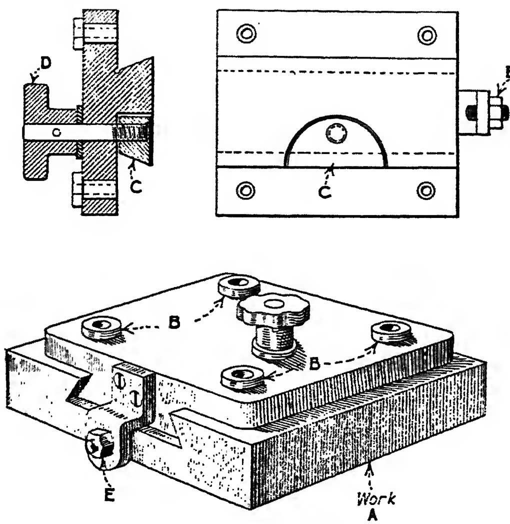


Fig. 79. Jig for a Dovetail Slide

on the surfaces marked *f*. It is necessary to locate the work so that the hole *C* is in a fixed relation to the hole *B* which must therefore be used as a locater. The work is set up on a stud at *B* and clamped by means of a swinging C-washer *D* through the nut *E*. It will be noted that the C-washer is pivoted so that it will swing clear of the work. By making the washer in this way loose pieces in the jig are avoided, which is always an advantage. The other end of the work is located under the bushing *C* by means of the sliding V-block *F*, operated by means of bayonet-lock and screw-bushing shown at *G*. This construction allows for variations in the boss on the work at the point *C* and at the same time a quarter turn of the knob *H* releases the V-block and allows it to be pulled back sufficiently so that the work can be removed from the jig. There are many cases where

this construction is extremely valuable as it permits rapid action and the mechanism is at the same time simple and easy to manufacture. This is a very good example of an open jig for a piece of high production work and the principles illustrated can be applied in numerous cases.

Open Jig for a Shaft.—Fig. 81 shows an open jig of excellent construction. The shaft *A* has been completely machined before the work is drilled. It is necessary to locate the drilled hole *B* at 90 deg. from the keyway in the taper at *C*. The work

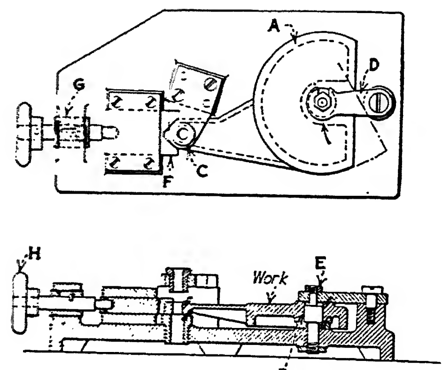
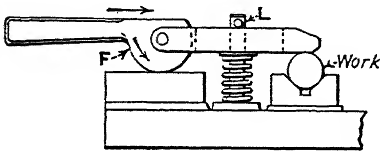


Fig. 80. Open Jig for a Lever Arm Bracket

is placed in V-blocks and located against the stop *D* at one end. The sliding member *E* is arranged so that it will locate in the keyway. A cam lever shown at *F* is used to clamp the work. The clamp is so made that it bears at *G* and *H* simultaneously. A slot at *K* allows it to be slid back away from the work when loading or unloading. A suggestion is made in regard to the construction of the pin at *L*. Two methods can be used, the one shown in the drawing being the cheaper. The enlarged view at *M* shows an improved method which is more substantial but also more expensive. The designer must be governed by the size of the stud at *L* and if it is found that the pin is not sufficiently strong to withstand the pressure of the cam lever, the improved construction *M* can be used. A jig of this kind is rapid and its operation makes it very convenient to handle.

The jig shown in Fig. 82 is an open jig which, however, is

close to the border line between the open and closed types. The work *A* is a pump cover which has been machined on the surfaces marked *f*. It is to be drilled at *B, C, D* and *E* in this operation and it is necessary that these holes should bear a correct relation to the outlet *F* as well as to the previously machined surface and also to the outside diameter of the work. The



Elevation Showing Clamp

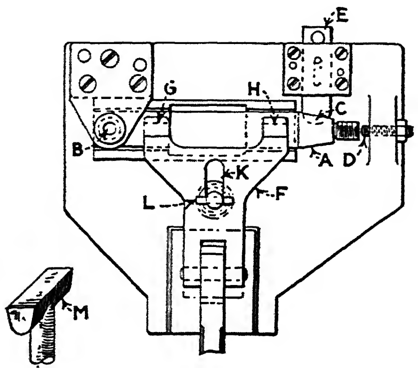


Fig. 81. Open Jig for a Shaft

method of locating the piece is rather out of the ordinary. The casting rests on four hardened bushings directly under the holes *B, C, D* and *E* and the spout *F* is located against the hardened locating pin *G* through the action of the bevel spring plunger *H*. It is also given another location, with respect to its outside diameter, by contact with the locating pins *K* and *L*, which are fixed in the body of the jig. After the operator closes the lever *M*, when the work is in position, the clamp *N* is screwed down on the work by means of the thumbscrew *O*. It will be seen that this clamp is not directly above the locating bushings on which the work rests, yet there is no danger of distortion on account of the stiffness of the casting. The portion of the work opposite the points *K* and *L* and mid-way between them strikes

the angular surface of the spring plunger P which depresses and at the same time insures a positive location against the two pins K and L.

The locking of the leaf is by means of a quarter-turn screw shown at Q. This jig is rather exceptional in its general construction and may be considered as an excellent example of modern jig design.

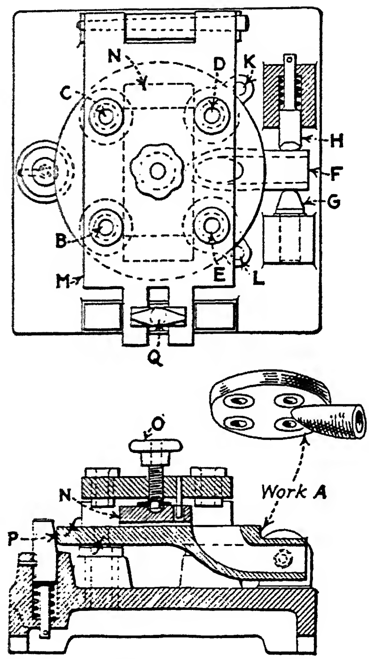


Fig. 82. Open Jig for a Pump Cover

Importance of Chip-Clearance in Closed Jigs.—In closed jig design particular attention must be paid to the clearance around the work in order to have plenty of room for chips to accumulate, for cleaning, and for setting up and removing the work. Wherever possible in closed jig design it is a good idea to core openings in the side of the jig in order to allow for cleaning. A very good example of a closed jig of simple construction is shown in Fig. 83. The work A is a casting which has been finished at f in a previous operation. There are three blind holes to be drilled at B, C and D and it is necessary to

locate the work from the finished side of the casting, from the boss around the hole *D* and to provide another locater which will come in contact with the rough casting on the side as indicated at *E*. In the design of the jig it is well to note that the stud *E* could be so made that it would be adjustable, but in this case it has not been done because the casting is known to be a good one and not subject to variations at this point. The boss around the hole *D* locates in an adjustable V-block, the con-

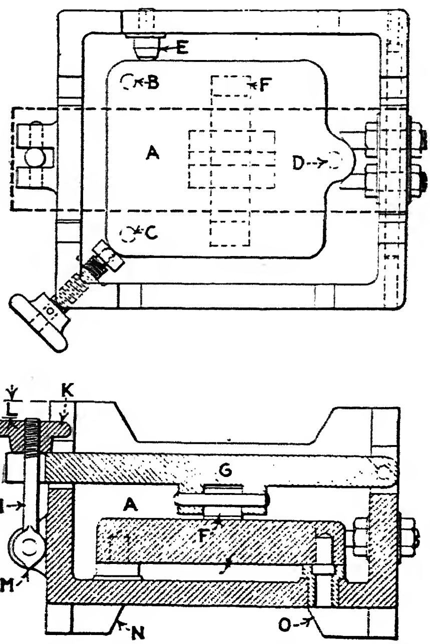


Fig. 83. Closed Jig with Clamp in Leaf

struction of which has been mentioned in a previous article. The work is clamped in position by means of the screw at the corner adjacent to the hole *C*. It is advisable to set this thumbscrew at an angle of 10 or 15 deg. so that the action will tend to force the work down on the finished surface *f* as well as to carry it into its correct location. The work rests on the heads of the three hardened bushings at *B*, *C* and *D*. These bushings are slightly different from the regular type in that they are counterbored slightly to allow for chips while drilling. The method

of clamping the work is by means of an equalizing clamp *F*, which is mounted in the leaf *G*. Attention is called to the fact that the clamping action is not directly over the points in which the work rests, but it can easily be seen that the thickness of the casting is such that there is little likelihood of its being distorted by the pressure of the clamp. The leaf is clamped by means of the swinging eyebolt *H* and the thumbknob *K*. Care must be taken to allow plenty of clearance at *L* so that there will be no chance that the screw will strike the drilling-machine table before the leg does. The eyebolt is so made that it will not revolve completely on account of the end *M*, which strikes the wall of the jig as the eyebolt is thrown open. When in use this jig is turned over so that the work is drilled from the side opposite the leaf. The jig feet *N* and *O* should not be made too long as they might interfere with the drill chuck. There are several important points of general construction involved in the design of this jig.

Closed Jigs for Angular and Straight Holes.—When large castings are to be drilled from several sides, the jig is frequently made in trunnion form, but when the work is comparatively small it is customary to provide for drilling the holes from various directions, by making it possible to set the jig up in different positions as required. When some holes are to be drilled straight and others at an angle in the same jig, care must be taken that projecting knobs, setscrews or other protuberances, do not strike the surface on which the jig is resting. In Fig. 84 a closed jig is shown for the work *A* which has been previously machined in a turret-lathe operation at *B*, *C*, *D* and *E*. There are four holes to be drilled at *F*, arranged at the four corners of a rectangle. There is also an angular hole to be drilled at *G*. The work is located on the fixed plug *H* at one end of the jig and rests on the hardened ring *K*. At the other end a plug *L* is used as a locater. It will be noted that this plug is arranged so that it can be operated quickly. The method used is an application of the familiar form of bayonet-lock, the plug being slotted at *M*, and the slot having an angularity at *N* to provide for locking by means of the teat screw *O* which engages with the slot.

As it is necessary to locate the finished pad containing the four holes *F* in such a way that the holes mentioned will be

square with the finished surface, a locater must be provided. The form of locater used is shown in an enlarged section. The plug *P* is made with a double end at *Q* and *R* so that these two points bear against the casting and straighten it up in relation to the finished surface. The plug is mounted in a bushing and is controlled by a spring. The end of the bushing is slotted to

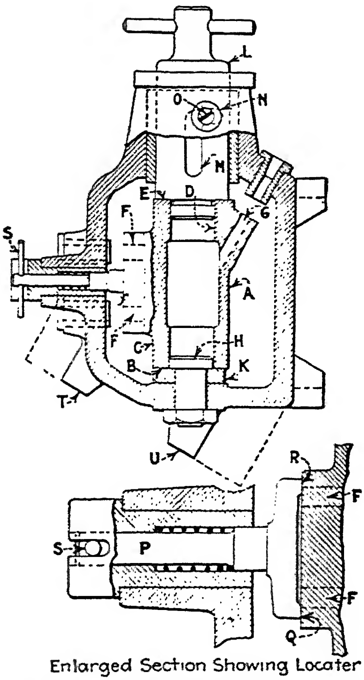


Fig. 84. Closed Jig for Angular and Straight Holes

receive a pin *S* which keeps the locater in its correct position, provides a means for withdrawing it when inserting the work, and acts as a restrainer to prevent it from coming out of the bushing. It can be seen that the action of the locater is practically automatic after the work is placed in the jig and tends to straighten out the finished surface and thus bring it in to its true position while the plug *L* is being operated.

As originally designed four feet were provided at *T* and *U* in order to give support while drilling the angular hole *G*. The construction would be much improved by extending these feet

and separating them farther, as indicated by the dotted lines, in order to give greater stability.

Simple Type of Closed Jig.—A conventional form of closed jig is illustrated in Fig. 85. The work *A* locates on a hardened plate *B* which is set in the body of the jig. The bushings *C* are carried in the leaf. The work locates on a central stud *D* and is clamped by means of C-washer *E*. Provision is made in the

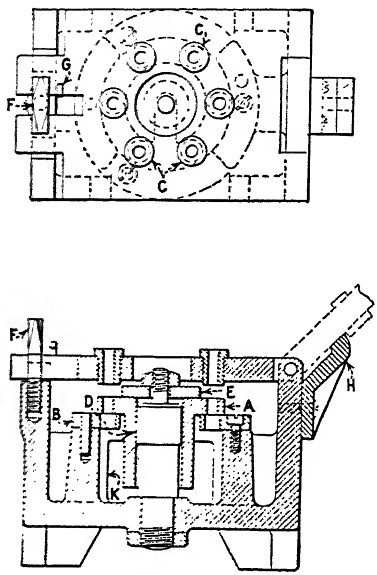


Fig. 85. Simple Type of Closed Jig

leaf for the nut on top of the C-washer in order to bring the leaf as close to the work as possible. The leaf is changed by means of a quarter-turn screw shown at *F* and a stop-pin is provided at *G*.

Attention is called to the leaf stop indicated at *H*. It is also well to note the manner in which the stud *D*, on which the work is located, is arranged and that the wall of the jig is opened up on two sides at *K* in order to provide for cleaning. It will also be seen that the work does not get a bearing on the stud *D* for its entire length as it is relieved at the lower portions, yet it gives ample surface for accurate location.

A very good example which shows the application of a swing-

ing V-block to a jig is shown in Fig. 86. The work *A* locates in a block *B* at one end of the jig while the other end is locked and clamped by means of the two arms, *C* and *D*, operated by a thumbscrew at *E*. This application can be used in many cases, and the example will give the designer a number of good ideas in regard to the details of construction.

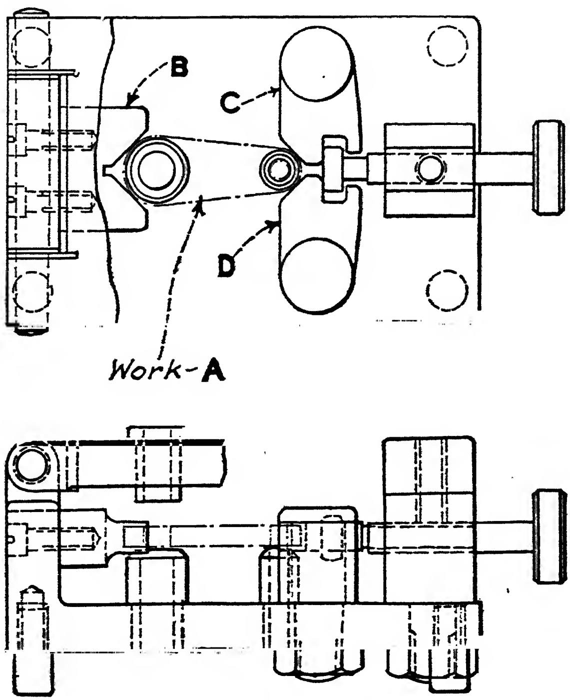


Fig. 86. Design of Jig with Swinging V-block

Built-up Jigs.—A number of units frequently used in the construction of built-up jigs have been illustrated and described in an earlier article. In the example shown in Fig. 87 some of these principles and units are illustrated.

The work *A* has been finished all over in a previous operation and it is located on the central stud *B* and also in the four pins *C*, *D*, *E* and *F*. The holes to be drilled are a blind hole at *G* and three smaller holes *H*, *K* and *L*. The depth of the blind hole is important and for this reason the leaf is provided

with two hardened and ground stop-pins at *M*. The enlarged view shows the type of gage used for determining the depth of this blind hole. The hardened pins *M* act as stops for the gauge block *N* and the point *O* gauges the depth of the hole. If the hole is not deep enough the gage will not come down on the pins, while if it is too deep the gage can be turned around so that it will pass between the pins and strike on the sides.

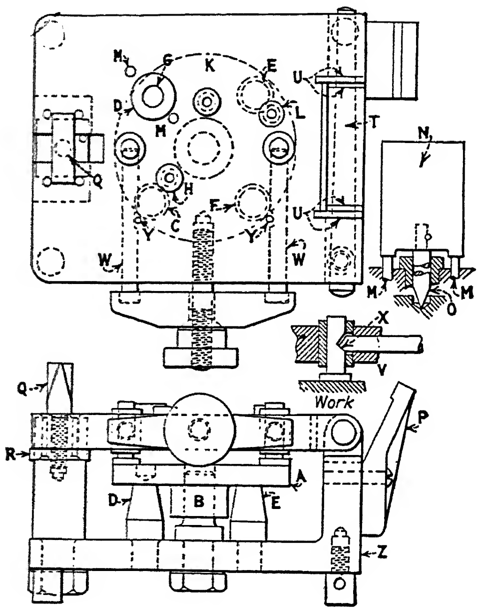


Fig. 87. Built-up Jig of Representative Type

This jig is provided with a leaf stop of standard form shown at *P* and the leaf is fastened by means of the quarter-turn screw *Q* and bears on the wear plates indicated at *R*. Provision is made for stopping the quarter-turn screw by means of the pin *S*. The construction of the hinge is of the approved method previously described, in which a taper pin *T* and wear plates at *U* are employed. The work is held firmly in position on the locating studs by means of a special equalizing clamp in the leaf. A sectional view of the construction is shown at *V*. It will be seen that the pins *W* are cut on an angle at the end *X*

so that they exert a downward pressure on the pins which clamp the work. The action of the operating pins is limited by the slots at Y so that they do not disengage completely from the angular slot X.

This jig is built up from a standard angular plate Z and a number of units previously described have been used in its construction. It is an excellent form of jig because it can be made up from standard units to some extent, is very easily cleaned, quickly operated, and has every provision for adjustment and replacement to take care of wear. It may be argued that the clamping does not take place directly over the locating studs but it has been pointed out that this principle cannot always be followed, and in the case shown the work is sufficiently stiff that no danger of distortion need be apprehended

Locating and Assembling Jigs.—It is often necessary to assemble a number of pieces on a shaft in a certain relation to each other both radially and longitudinally. When this is necessary it is advisable to make use of a locating jig, an example of which is shown in Fig. 88. The work consists of a shaft A to which are applied several collars at B, C and D, fastened to the shaft by means of taper pins. The jig is of cast iron and the various units necessary are mounted on it. The shaft A, with collars B, C and D loosely assembled on it, is forced up against the hardened stud E by means of the thumbscrew F. Each of the collars is held in position and prevented from turning by means of a screw G mounted in a block H. The screws force the shaft over into V-blocks and longitudinal location of the various collars is assured by the space between the various blocks.

The principle shown at G is also used at B and D, but the position of the unit is shown in dotted lines in order to make the illustration more clear. The leaf K is provided with bushings at L, M and N by means of which the holes are properly located. The work being clamped independently of the leaf, a tapered reamer can be used to finish the holes after the leaf has been thrown back into the position shown. Applications of the principles shown can be used for other work of similar character.

It is frequently necessary to locate gears, cams, levers, or other parts on a shaft in a certain relation to each other. In cases of

this kind it may be possible to use a jig similar to that shown but with different schemes for locating. The gear shown at *O* is to be assembled on a shaft and it is necessary that the gear teeth should have a certain relation to other members on the

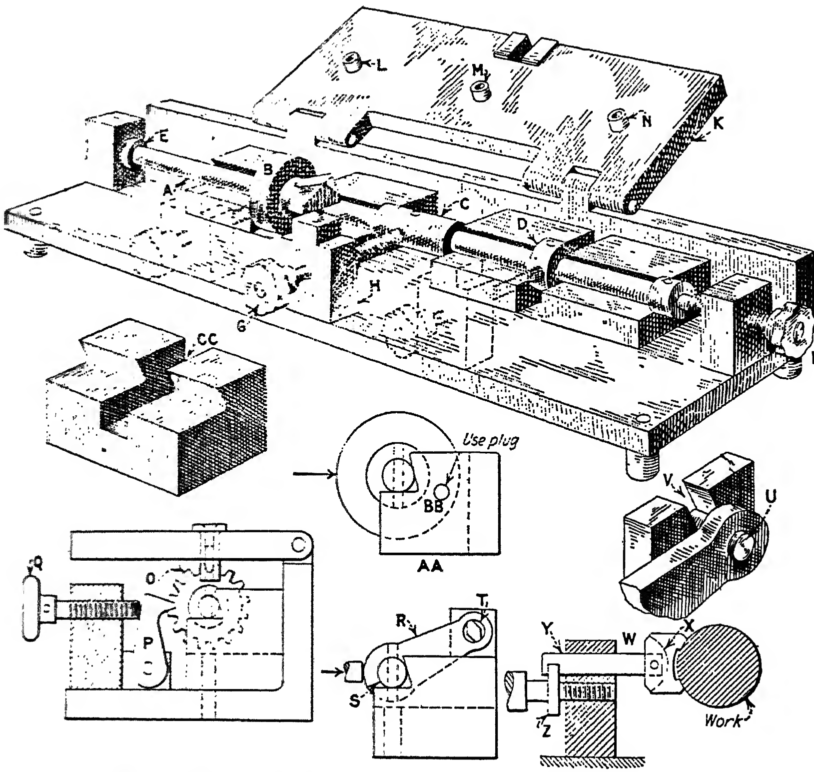


Fig. 88. Locating and Assembling Jig for Shaft and Collars

shaft. The pawl *P*, used to give this location, is operated by means of a thumbscrew *Q*. A spring can be applied to throw the pawl out of location when the screw is released.

Another example is shown at *R*. This is a lever which must be located on the shaft at *S* and in the correct angular relation to the hole at *T*. It is a simple matter to provide a pin at *T* to give the desired position, the pin being cut away as indicated in order to provide for slight variations between the center distances of the two holes. When pressure is applied in the direc-

tion indicated by the arrows the shaft will be forced into the V-block and the lever will be held in its correct position.

There are some cases where a pin is assembled in the lever arm as indicated at *U*. When this is the case a locating block may be slotted as at *V* to receive the pin. The angularity of this slot should be at right-angles to a center line passing through the two holes in the lever.

A method which can be used for locating work in a V-block is indicated at *W*. A swivel block *X* is mounted on the end of

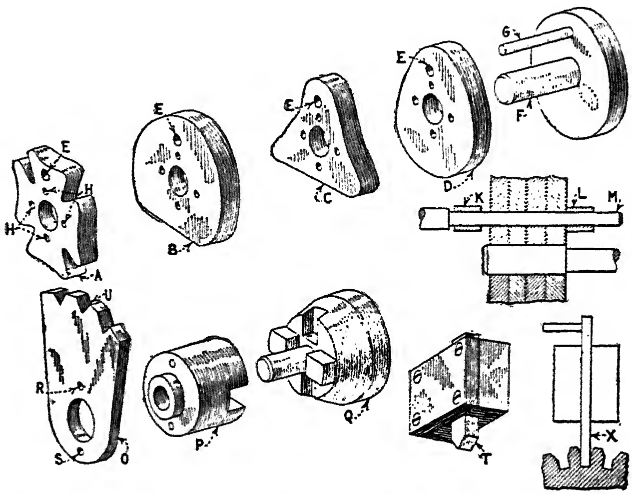


Fig. 89. Examples for Practice in Designing Locating Jigs

a stud *Y* and operated by means of a collar screw *Z*. This type of clamp has an advantage when it is necessary to guard against any turning action which might change the position of the work when clamping. Occasionally a collar must be located on a shaft in relation to a previously drilled hole such as that indicated at *AA*. The work can then be located in a V-block and a plug can be pushed into the collar at *BB*. This sketch also illustrates the slotting of a single V-block to provide for location instead of using several blocks as indicated on the jig. *CC* is also slotted but in a direction different from that in the example just mentioned.

Example for Practice.—When a series of parts is to be assembled such as the cams shown at *A*, *B*, *C* and *D* in Fig. 89,

it is common practice to provide the cams with a driving hole such as that shown at *E* in each cam. This hole is carefully located and is used in cutting the cam and in assembling. The parts are generally set over a small plug similar to that shown at *F* and are located by means of the pin *G*. A jig of suitable size is made, either cast or built up, in such a way that the pieces are all located one over the other on the plug mentioned. A suitable clamp must be provided to hold the four pieces firmly in position. After they have been assembled the rivet holes *H* are drilled. It sometimes happens that the pin *G* is weak and is likely to be bent when in use. It is better to provide the jig with bushings as indicated at *K* and *L*. After this is done a plug *M* can be placed through all of the holes one after the other to give the correct location.

A good problem suggested here is the designing of a jig for drilling the rivet holes *H* in these cams.

Another example which offers a good problem is afforded by the parts *O, P* and *Q*. *O* sets over *P* and *P* over *Q*, and a locating jig is desired so that the rivet holes *R* and *S* can be drilled in their correct location. As an alternative we suggest that a locater similar to that shown at *T* can be used in the teeth *U* but if this appears too expensive a paddle gauge or plug such as that shown at *X* can be used.

On certain classes of work assembling and locating jigs are of extreme importance and it is therefore a good idea for the designer to note the construction of the examples given very carefully and put into practice the various principles which have been illustrated and described. He will find it a decided advantage to design several jigs of this kind, using examples from his own practice and taking cases which are of particular interest rather than those which appear simple and easy to work out.

CHAPTER V

INDEXING AND TRUNNION JIGS

Indexing Requirements—Drilling and Reaming Indexing Fixtures—Four-Sided Jigs for Accurate Work—Principles and Methods of Indexing—Index Plungers and Latches—Combined Index and Latch—Specific Examples of Indexing Jigs—Roll-Over Jigs—Trunnion Jigs—Double Trunnion Jig—A Difficult Drilling Problem—Trunnion Jig Used Progressively.

When a piece of work is to be drilled from three or four sides it may often be desirable to locate it in some form of indexing or trunnion jig. Speaking generally, the necessity for a trunnion jig is indicated when the work is of large size or when the angularity of the holes would not permit the use of a closed jig. It is evident that a large closed jig, say 20 x 18 x 15 in., would be very cumbersome and difficult to handle when turning it over to drill the work from the various sides. Also if the holes in the work were to be so located that the angles did not diverge greatly from each other, it would be practically impossible to drill the holes unless the pieces were located in an index jig of some kind.

The tool engineer in making a decision as to the type of jig to be used for the work must analyze the conditions under which the jig is to be used and must also pay attention to the following points which affect the design.

Points To Be Considered.—(1) The ultimate production for which the jig will be required. This is an important factor in the design, as it is evident that it would not be economical to design an indexing jig for a piece of work on which the production is small. It would be better to make several simple and cheap jigs rather than to design one expensive trunnion jig.

(2) The number of sides from which the work must be drilled.

It is difficult to give a fixed rule as to when a trunnion jig may be called for and it should be noted that the number of sides from which the work is to be drilled does not, necessarily, settle the matter. We can easily assume that a piece of work having holes in four sides might be of such form or size that it would not need to be handled in an indexing or trunnion jig. On the other hand if the work were very large and difficult to handle it might even be necessary in some cases to design a trunnion jig, even if the holes were drilled from only one side of the piece, in order to facilitate loading and unloading.

(3) The machines on which the various drilling operations will be done. This factor is an important one and must always be given early consideration. There are many cases where multiple spindle drilling machines can be used in connection with trunnion and indexing jigs, provided the holes are more or less uniform in size. There may be other conditions which would indicate that a radial drilling machine must be used. There may also be cases where a light sensitive drilling machine with only one spindle or with several spindles carrying drills of different diameters arranged in gang-form may be necessary.

(4) Loading and unloading: In placing the work in the jig and removing it after it has been drilled attention must be paid to the convenience of operation. If the work is heavy it is evident that the operator must be considered to some extent so that he will not be obliged to load the work from an awkward position. For the sole purpose of making the method of loading and unloading as easy as possible, it is often desirable to make a trunnion jig with a special loading position. When the work is small such provision is not necessary in the majority of cases. It is sometimes a great convenience to the operator if the jig is provided with ejectors of some form and when this is done care must be taken that the pressure of the ejectors is exerted in such a direction that there is no possibility of a cramping action when in operation.

(5) Locating and clamping: In the location of the work and in the clamping thereof the weight of the work which is to be drilled is an important factor. For very heavy and large castings the matter of leverage which must be exerted on the work to force it into a correct position must be carefully thought out by the tool designer. Cam levers, handwheels, bayonet lock

plugs and other devices may often be necessary to insure the correct location. In clamping the work in a large trunnion jig the clamps should be so proportioned that when they are set up they will not cause distortion and thus interfere with the proper working of the jig.

(6) Clearance when indexing: This is an important point which is likely not to be given the consideration which it requires. When large work is being handled on a trunnion jig it may often be found desirable to clamp the jig to the table of the drilling machine. It is evident that when the jig is indexed it should not interfere with the setting of the machine spindles, nor should it strike the column of the machine. The writers know of a large trunnion jig, designed to be used on a heavy drilling machine with a special multiple drill head, which when swung interfered with the column of the machine. It was found necessary to provide a special mounting for the base of the jig so that it could be moved away from the column each time it was indexed. Such mistakes can be avoided if the tool designer will provide himself with data showing the various clearances on the machine to be used for the work.

Having considered the various points mentioned in connection with the design of indexing and trunnion jigs let us now proceed to a discussion of the design of various types of jigs which come under this heading. We may have (a) a number of holes which are drilled so close together that it is not possible to arrange the spindles of a drilling machine to drill all of the holes at the same time; (b) a number of holes in a circular plate at the same distance from the center; (c) several holes in line with each other which must be drilled separately on account of the spindle spacing on the drilling machine; (d) a number of holes equally spaced in the periphery of a cylinder; (e) angular holes arranged in various ways.

Indexing Requirements.—It is obvious that both the shape of the work and the relation of the various drilled holes to each other are factors important in determining the type of indexing jig most suitable for a given piece of work. There are given in Fig. 90 several examples of work showing a variety of conditions: *A* is a circular plate having four holes *B* equally spaced and at the same distance from the center. There are several ways in which this piece of work can be drilled. One way is

to make a drill jig with four bushings and move it about on the table of the drilling machine so as to bring each bushing under the spindle. Another way is to use the same jig, drilling with a four-spindle head. Still another way is to make an indexing jig, a suggestion for which is given in the illustration. A drill

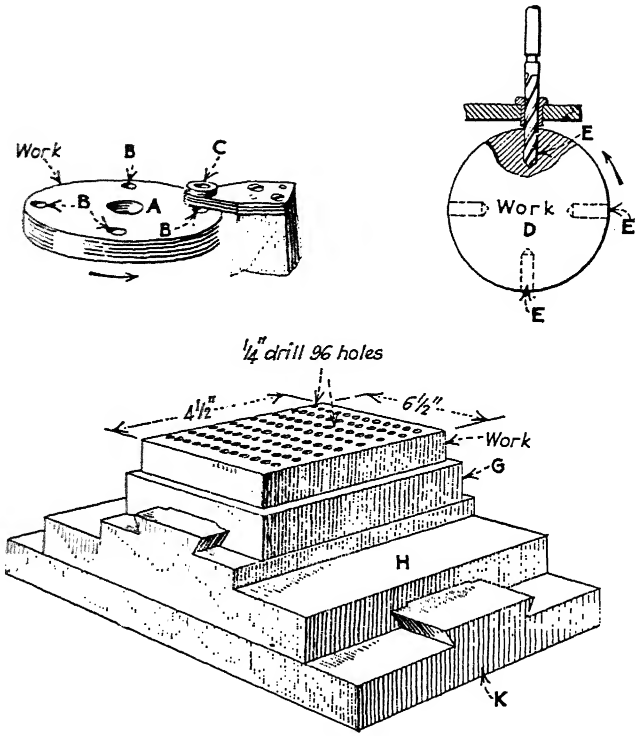


Fig. 90. Several Examples of Work Requiring Indexing Jigs

bushing of the proper size would be fixed as shown at *C* and the work would be placed on an indexing table or disk.

At *D* there is shown a drum in which four holes *E* are to be drilled. This operation can be done in either an ordinary four-sided jig or an indexing jig.

The plate *F* offers the rather exceptional problem of drilling 96 holes, ¼ in. in diameter and ½ in. c. to c. in each direction, a problem with which we had to deal quite recently. It would be impossible to arrange a series of drill spindles close enough to-

gether to drill all the holes at the same time, but it would be entirely practicable to drill alternate holes in one or two lines at the same time. Hence the logical method is to mount the work so that it can be indexed in two directions in a horizontal plane. Suitable provision for carrying the bushings would be made in the jig and the required stops or indexing points on the two slides *G* and *H* would give the various positions. The piece *K* would be clamped to the table of the machine.

A number of combinations of drill spindles could be made when drilling a piece of this character. If the machines were to be multiple-spindle drilling machines, the heads could be spaced to drill alternate holes in the first line and the corresponding holes in the third line. The plate could be indexed in one direction only so that the intermediate holes could be drilled. Several indexing operations all in one direction would complete half of the drilling. After this the other slide operating in the other direction could be indexed progressively to complete the work. It is possible to handle a piece of work of this kind by means of automatic attachments through which the indexing mechanism is operated by the action of the drill head when it is lifted from the work.

Index Boring and Reaming Jig.—In Fig. 91 is shown an example of an indexing jig in which the two holes *A* and *B* are to be bored and reamed without removing the work. Bushings could be carried on the sliding member *C* or a permanent bushing could be supported on the column of the machine. The work is of large size and as a consequence indexing is done by means of lever *D* which operates pinion *E* meshing with rack *F* on the sliding member *C* of the fixture. Location bushings are provided at *G* and *H*. The slide is shown in the neutral position. Attention is called to the adjustable stops *K* and *L* which approximate the location as the slide is indexed from one position to the other, thus making it easier for the operator to insert a pin in the location bushings. This example is not intended to show details of construction but rather the application of a principle.

In designing a jig of this character it is advisable to make the lever *D* long enough to afford easy operation. Care must be taken that the pinion *E* is large enough to index the work without too great radial motion of the lever. If the holes *A*

and B are spaced so far apart that a very large pinion would be required it is better to make the pinion small and provide the lever with a reversible ratchet. Both ratchet and pinion should as a rule be covered to exclude chips.

Swivel Index Jig.—A simple form of indexing jig is indicated in Fig. 92, in which the work A has two holes at B and C. The jig itself consists of a box D pivoted at the point E. It is indexed by means of the handle F. Hardened studs G and H are provided to bear against the adjustable stops I and J. Bushings could be provided to give more accurate location, but for light work the method shown would give good results.

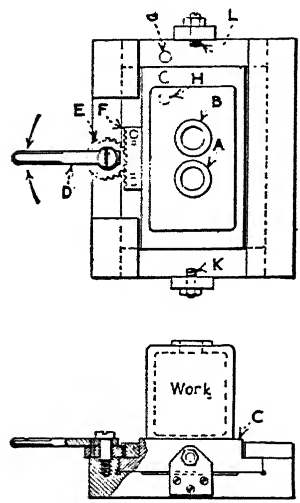


Fig. 91. Index Jig for Boring and Reaming

The same principle could be applied if there were three holes instead of two, but another method of indexing would be required. It would be necessary to find the common center for the three holes and pivot the swinging member at that point in order that the bushings would come directly under the drill spindle. There are certain isolated cases where such a jig would be found very useful. A rapid indexing device could be used and various modifications made to suit particular conditions.

It frequently happens that a piece of work similar to that shown at A in Fig. 93 is to be drilled at two or more points such as B and C, the holes to have an angular relation to each

other. When the two holes are to be close together and drilled from the same side of the piece, it would not always be ad-

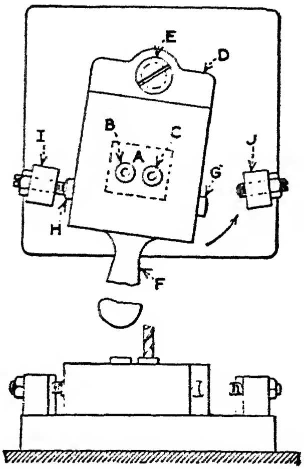


Fig. 92. Swivel Indexing Jig

visable to build an indexing jig, on account of the cost. Assuming then that the holes are to be drilled in a simple jig having the form shown at *D*, it would not be difficult to make up a

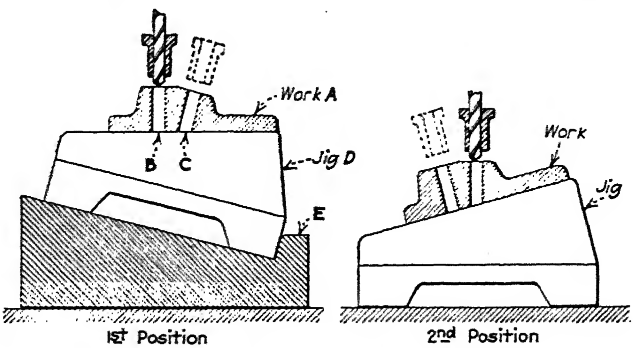


Fig. 93. Angular Plate Used in Connection with a Simple Jig

special angular plate such as shown at *E*, on which the jig could be located at the proper angle for drilling the hole *B*; after this hole had been drilled the jig could be taken from the plate and placed on the drill table to drill hole *C*, as shown in the second position.

If the production required on the work were considerable the angular plate could be clamped under one spindle of a two-spindle machine for drilling one hole and the jig could be transferred rapidly to a position on the machine table under the second spindle for drilling the second hole. Occasionally on very large work an angular plate, such as that shown, will save the cost of a trunnion or indexing jig.

Four-Sided Jig for Accurate Work.—The requirements of certain classes of work are such that it is not always desirable to use an indexing jig or fixture, especially when great accuracy

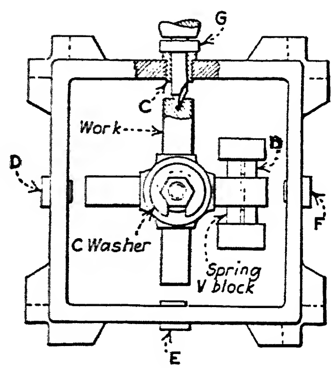


Fig. 94. Four-Sided Jig for Accurate Work

is necessary. In the majority of cases an indexing jig will give results well within the limits of accuracy necessary, but there are occasional instances when some other method may be preferred. There is always the possibility of a slight inaccuracy resulting from the use of any indexing mechanism, caused by chips or dirt working into the indexing members or by wear, misuse or neglect.

An example of very excellent construction to be used when great accuracy is required is shown in Fig. 94, the piece of work *A* being a cross which carries four gears on the arms. It is important, not only that these arms be at right angles but that the locations of the center-holes in the ends of the arms should be of the same depth and the same distance from the center hole on which the work is located. The work is located on a center stud and clamped by means of the C-washer, one of the arms being located in a spring V-block shown at *B*. The jig is pro-

vided on four sides with feet which can be very accurately machined. The bushings *C*, *D*, *E* and *F* also can be located with great accuracy and can be faced so that they are exactly the same distance from the central locating plug. The depth of the countersinking is determined by the collar *G* which strikes the head of the bushing.

Simple Index Jig.—It is sometimes necessary to design a jig for drilling a series of holes which are equally spaced in the periphery of a shaft or some other part of a similar kind. An example is shown in Fig. 95 in which the holes shown in the

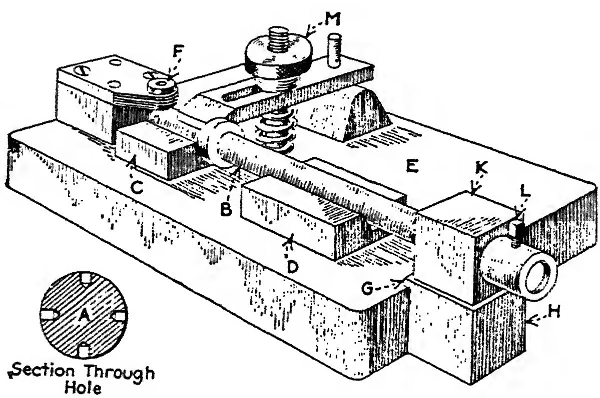


Fig. 95. Simple Index Jig

sectional view at *A* are to be drilled in the shaft *B*. The method illustrated here is not recommended for use except in rare cases; it may be found useful when a simple and cheap method is required for a comparatively small number of pieces. The accuracy obtained will be found to be very satisfactory. The work *B* is located in V-blocks at *C* and *D* and the jig *E* is provided with a bushing at *F* located centrally over V-block *C*. The upper surface *G* of a hardened block *H* is ground to a fixed distance below the center line of the V-blocks. A supplementary block *K*, which has been accurately squared up, is clamped to the end of the shaft by means of the setscrew *L*. By loosening the clamp operated by the thumb nut *M* and pushing the clamp back out of the way the shaft can be turned until the block *K* has rested on each of its four sides and the work has been drilled in each

of the four positions. The block K can be made with three, four, five, six, eight or more sides.

In quantity production it is often desirable to drill a piece of work and ream it in the same jig. Many times when this is to be done slip bushings are employed in the jig and the drill is replaced by a reamer in the drilling machine. A method which can be used is illustrated in diagram form in Fig. 96. Briefly

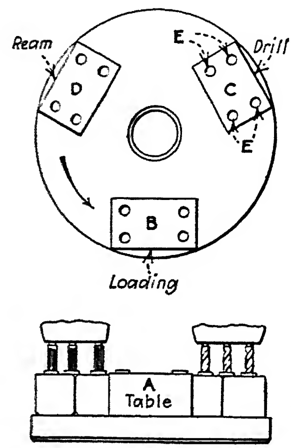


Fig. 96. Index Drilling and Reaming

stated the principle employed is that of an index table A on which are mounted three jigs that are indexed from loading position B to drilling position C, to reaming position D and back to loading position. A method like this is suitable only for high production. But it will be found to be an advantage in many ways when the nature of the work will permit. Changing from drilling to reaming bushings can be done by pivoting a plate containing four bushings of each kind or it can be done by using an outside bracket for the bushings.

Principles and Methods of Indexing.—In discussing the methods used in indexing various fixtures for drilling we must first consider the matter of accuracy. It must be remembered that indexing surfaces, plugs, bushings, wedges or any other members which are used to locate from in the process of indexing should be kept as free from chips and dirt as possible in order that the indexing may be accurate. This is a fundamental

point which must always be thought of by the designer. Let us refer to Fig. 97, in which two indexing plugs are shown at *A* and *B*. The design shown at *A* has a plug which is located radially so that it will enter the index plate *D* as far from the center *E* as possible. It may even be advisable to make a very large index plate for a comparatively small index jig if the accuracy required is great. In example *B* the plug *F* is quite close to the center *G* so that any errors in indexing would be multiplied in the work in direct proportion to the distance of the surface being drilled from the center *G*.

It may be taken as a general principle that the further away

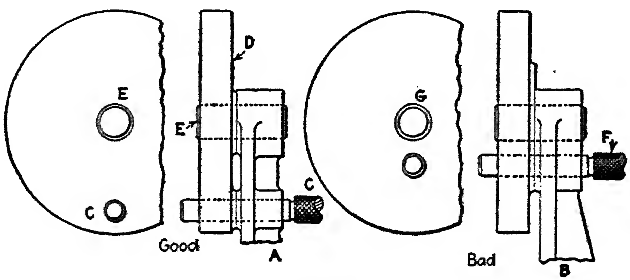


Fig. 97. Examples of Good and Bad Methods of Locating the Index Pin

from the center the indexing pin can be located the more accurate the work will be.

Index Plungers and Latches.—When an indexing jig is rotated into its various positions there must be a positive method of location provided for each position. There are a number of methods in common use, some of which are illustrated in Fig. 98. The simplest type of indexing pin is shown by the first sketch. *A* is the indexing member and *B* is the fixed member. Each of them is provided with a hardened bushing, at *C* and *D* respectively, in such alignment that the plug *E* can be pushed into them to form a lock as the various indexing positions are used. An objection to this form of indexing is that the plug is a loose piece which may be easily lost; it may, however, be attached to a piece of closet chain, and fastened to the fixed member. It can also be arranged with a special bushing and a spring to keep it in place.

Another form of indexing plunger, shown at *F*, is used by

many designers and has much to recommend it. The plunger is tapered at the end and seats itself in the tapered end of the bushing *H*. It has a long bearing in the bushing *K* and is provided with a spring to hold it in position. Some designers pre-

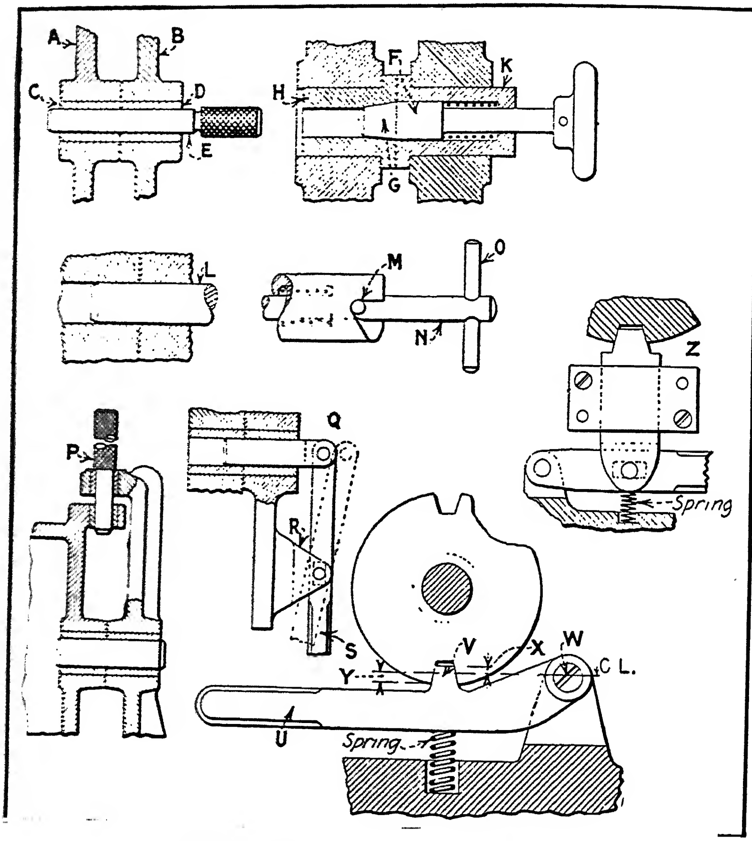


Fig. 98. Index Plungers and Latches

fer a straight pin instead of a taper, as indicated at *L*. The writers believe that this is a matter of personal preference although it is claimed that a taper plunger will adjust itself for wear when the straight plunger will not. Care must be taken in designing a tapered plunger, and the sides should not taper more than 10 or 12 deg. on each side of the center line.

In some cases it is necessary to use a heavy spring for holding

a plunger in position; a construction that requires considerable pulling on the part of the operator. This can be remedied by inserting a pin in the stem of the plunger as indicated at *M* and then cutting a cam-path on the end of the bushing at *N*. The insertion of a rod handle at the end *O* makes it possible to pull out the plunger by a turning action, much easier than a straight pull.

A form of index which is much in use on large work and which has the advantage of placing the pin as far as possible from the center, is shown at *P*. There is no particular comment to be made on this method except to say that it is good.

On large trunnion jigs it is often difficult to operate a pull-pin by means of a knob and it is much more convenient for the operator to provide a lever. An example is shown at *Q*. A lug *R* is attached to the base of the fixture to act as a fulcrum for the lever *S*. The fulcrum should be so placed that the length of the lever will permit the operator to withdraw the pin easily. It is evident that an elongated slot must be provided in the lever or the index pin to take care of radial movement when a spring is used. Many times it is desirable to use a steel plate instead of a bushing as an index plate, as shown at *T*. In one of two methods that are common practice, the lever, as shown at *U*, is formed at *V*, so that it will seat itself in the angular slot in the steel disk *T*. When an arrangement of this kind is made the designer must be careful to position the center *W* so that the distances *X* and *Y* will be equal in order that the angles on the lever will coincide with the angles on the disk.

The other method is shown at *Z*. The plunger is mounted in a slide and is operated by a lever. The second method is to be preferred on account of its greater accuracy but space will not always permit its use. Care should be taken that the plunger is given a long bearing in the slide in order to obtain accuracy.

Combined Index and Latch.—In indexing fixtures for high production work and in other designs of indexing fixtures it is desirable to make a very quick operating index and latch, one which will be so nearly automatic that a man can operate it rapidly and without giving it much attention. Such a latch is shown in Fig. 99. This form can be used in many cases and can even be arranged so that the movement of the drill press

spindle as it passes up after drilling the work will index the fixture. A steel disk A, having a number of index slots B, is mounted on a center plug C to which the body of the jig to be indexed is attached. The lever D has a cam cut on it at E, this cam being used to control the movement of pin F in the latch G. The lever is provided with a dog H which engages with the edges of the various index slots. The lever itself swings freely on the

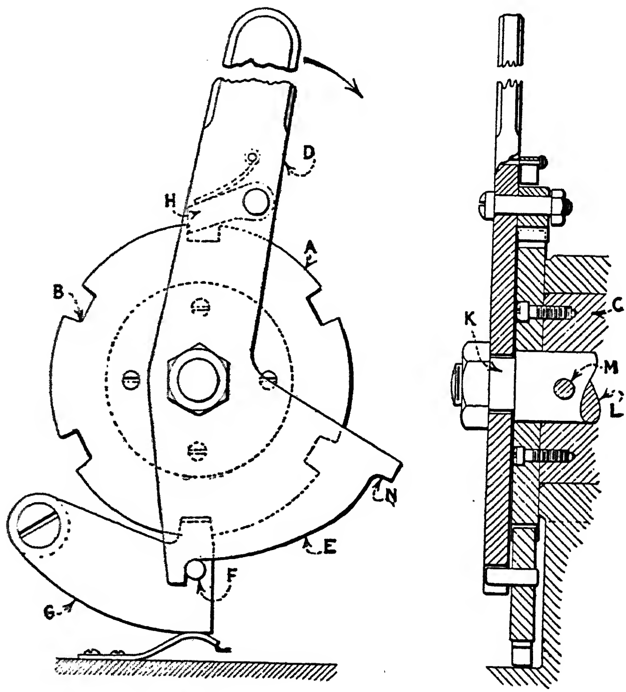


Fig. 99. Combined Index and Latch

bearing K which is a part of the stud L, fixed in the member C by means of the pin M.

In operation, when the lever is moved in the direction indicated by the arrow, the pin rides up on the cam thus pulling the latch out of the slot until restrained by the shoulder of the cam at N. At this point the dog drops into the slot and the lever is moved in the opposite direction until the latch drops into place once more, thus completing the indexing. This principle can be applied on both large and small jigs, preferably

for indexing from four to eight stations. All of the working parts should be hardened to insure long life and accuracy.

Index Table for Drilling.—In Fig. 100 is shown a form of indexing table which can be made up and carried in stock. It can be used for many purposes requiring a rapid and accurate index. Frequently, indexing of a number of holes is desirable and yet the number of pieces to be made is small, or for some other reason it does not seem advisable to make up an indexing fixture. In cases of this kind an index table can be used to

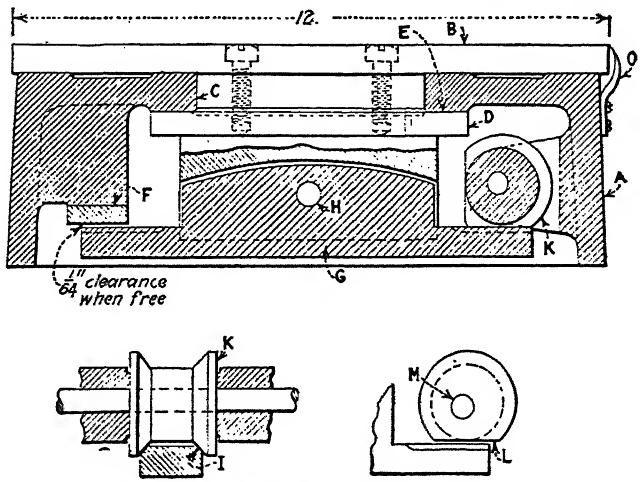


Fig. 100. Indexing Table for Drilling

advantage. A circular cast-iron base *A* has been faced on the upper surface and fitted with a table *B*, having a center bearing by means of the plug *C* to which it is firmly screwed. The plug has a flange *D* fitted to run freely against the surface *E*. A hardened shoe *F* is attached to the fixture at one side. The lower part of the bearing plug is slotted to receive the index rocker *G* which is pivoted loosely on the pin *H*. The upper surface of the rocker is beveled to the form shown at *I*. This bevel surface acts as the index for the plate when acted on by the spool *K*. The form of this spool is shown clearly in the diagram *L*, and it will be noted that the flatted side allows clearance for indexing. A great advantage in this type of indexing mechanism is the fact that there is clamping action of the rocker against the hardened block.

In the particular instance illustrated, the device is made for indexing to 180 deg., but the same principle can be used for various numbers of index spacing by making suitable modifications in general construction. The cam *K* can be operated from outside the fixture by means of a simple lever attached to the pin *M*. An approximation of the indexing used can be determined by reference to the pointer at *O*. The advantages of this device are that it is accurate, very rigid in construction and all the working parts are protected from dirt and chips.

Index Fixture for Holes in a Circle.—We referred to a condition in Fig. 90 in which a number of holes were drilled so close together that drill spindles could not be spaced close

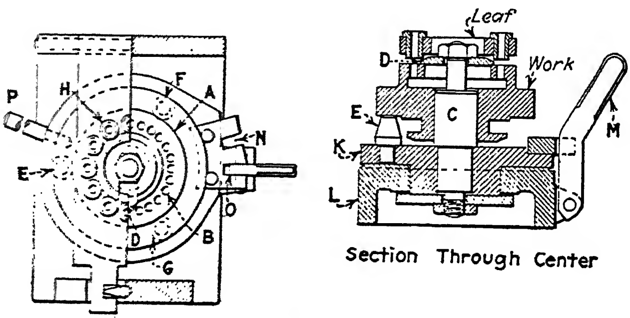


Fig. 101. Indexing Jig for a Number of Holes Close Together in a Circle

enough to drill them all at once, and we showed a method of handling such a condition. The holes were arranged in rectangular form. We will now consider indexing jigs arranged for a group of holes so spaced in a circle that it is not possible to set the spindles of a drilling machine close enough together to drill them all at one time.

Such a condition is shown in Fig. 101, the work being shown at *A* and the holes indicated at *B*. In this jig the work is set up and located on a central plug *C* and clamped in position by means of a C-washer *D*. It rests on the three pins *E*, *F* and *G*. The bushings are spaced for alternate holes as indicated at *H*. The stud on which the work is located is mounted in a revolving plate *K*, supported by the base *L*. Indexing is done by means of the lever *M* which engages with the slots *N* and *O* in a hardened plate. Another lever *P* is used to swing the index plate

from one position to the other. This is a very good example of an index jig to take care of a condition such as that frequently found in the main driving shaft clutch gear of an automobile. There are many other cases when a jig of similar form can be used, as the general simplicity of the construction makes it readily adaptable to a variety of conditions. Any one of the several methods could be used for indexing instead of the one shown. It is advisable to provide some means of fastening the jig down to the drilling-machine table.

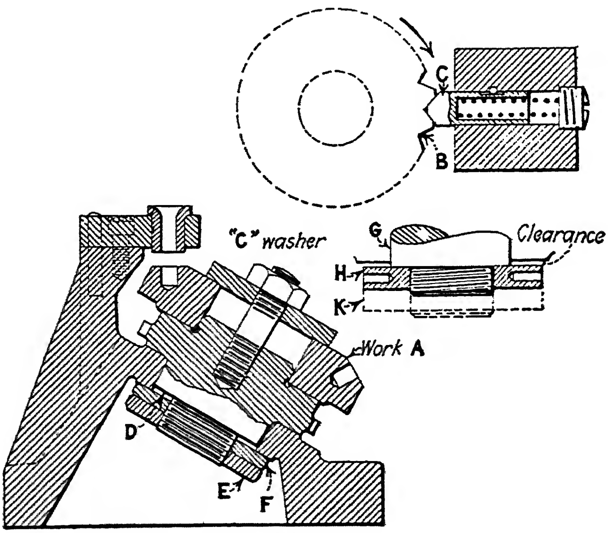


Fig. 102. Index Fixture for Angular Holes

Index Fixture for Angular Holes.—The fixture shown in Fig. 102 is an indexing drill jig for a series of blind holes drilled at an angle in the work *A*. Great accuracy in the location of the holes is not of supreme importance, and therefore a method of indexing can be used which will give approximate locations but not to exact dimension. The index plate has a series of notches cut in it at *B*, spaced in such a way as to give the correct spacing for the drilled holes. A spring plunger *C* with a rounded end is mounted in a block so that the plunger engages the notches in the index plate. A weak spring should be used when a design of this kind is made in order that the indexing may be as easy as possible.

The index plate can be mounted in either of two ways: As shown at D it is held in place by the two locknuts E and F, which are adjustable to permit regulation of the pressure on the bearing and adjustment for wear. A more common method of mounting is shown at G, where the stud is fitted so that it comes through the hole a few thousandths and is fastened by one or two nuts as shown at H and by the dotted lines K. If the work is to index in one direction only, one nut might be

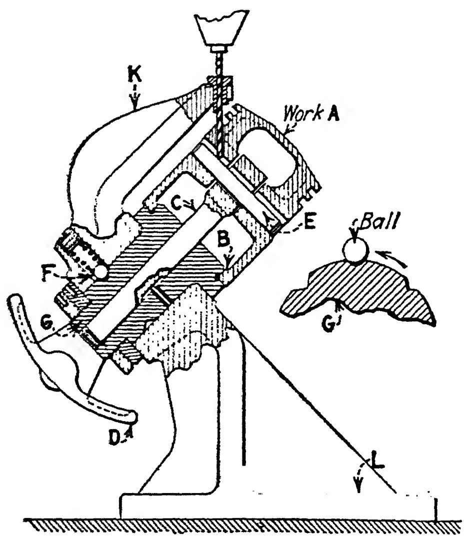


Fig. 103. Indexing Jig for Angular Holes in a Piston

sufficient, providing the direction of the indexing is such as to tend to tighten the nut rather than to loosen it. If the indexing is likely to be in both directions two nuts are necessary.

In Fig. 103 is shown another angular jig for drilling a series of angular holes in an automobile piston. The work A is located on a stud B and drawn down against its shoulder by the pull back rod C which is tightened by the hand knob D. In tightening this rod a clamping action takes place on the pin E inserted in the wrist-pin hole.

As the angular-drilled holes need not be particularly accurate in their spacing, the indexing is done by means of the ball F which snaps into notches cut around the plug G. The bushing

in this jig is carried in an overhanging arm K which forms a part of the jig body L. The designer should pay attention to the stability of jigs of this character and should provide a base of sufficient dimensions so that it will be well supported.

When several holes are to be drilled in a ring such as that shown at A in Fig. 104, two methods can be used. If there is available a multiple drill of capacity suited to the work, a simple jig can be made so that all the holes can be drilled at one time. If, however, such a machine is not available, one solution of the problem is to use an indexing jig. The type shown here is exceptionally good from the indexing point of view,

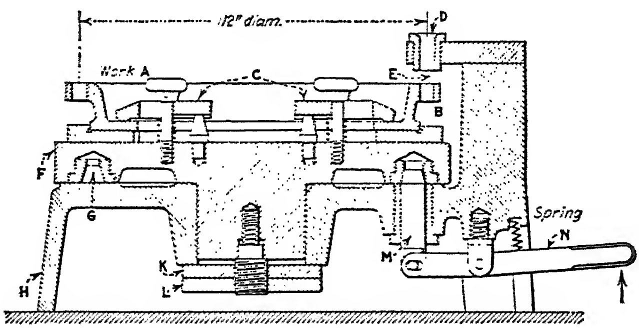


Fig. 104. Indexing Jig for an Annular Ring

because there is very little chance for dirt or chips to get into the mechanism and thus cause errors in indexing.

The work is clamped on the locating ring B by the sliding clamps shown at C and a bushing D is so placed that the holes will be located the correct distance from the center of the ring. Sufficient clearance must be allowed between the work and the bottom of the bushing at the point E so that there will be no difficulty in the removal of the work. The indexing mechanism consists of a circular plate F, in the underside of which are located the bushings G. The index plate is centered in the base H and is held in place by the two locknuts K and L.

The index plunger M is operated by means of the lever N which projects out through the side of the fixture in a location convenient for the operator. The work can be indexed either by pulling it around, by grasping the ring or by means of holes in the index ring F. This type of jig is excellent for many pur-

poses and the principles shown can be applied not only to drill jigs but to other indexing fixtures for various machining operations. It should be borne in mind that the class of work for which an index fixture is designed and the amount of pressure which it is called upon to withstand will affect to a large extent the general design and proportions of the fixture.

Fig. 105 shows a large jig designed for use in drilling a series

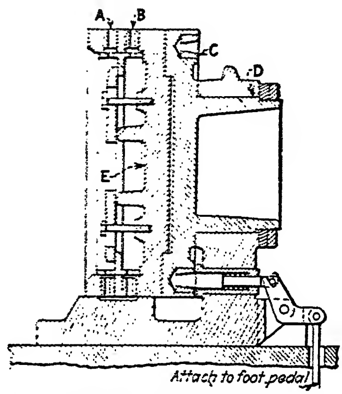


Fig. 105. Indexing Jig for Radial Rivet Holes

of holes *A* and *B* equally spaced around the periphery of an automobile brake band. This jig is quite different in construction from any of those shown previously and it may be considered in the nature of a "horrible example." In other words it is something which is neither practical nor well designed, yet it is expensive and much unnecessary work is involved in its construction. The entire construction is very clumsy and heavy. A very large bearing is given to the index plate *C*. The index plate and the casting *E* which carries the bushing, have been made separate, for no apparent reason except the possibility of breakage while machining the casting or on account of replacement in the event of serious wear in the index plate. In addition to these points a series of bushings *A* and *B* have been located around the periphery of the jig when two bushings that would have answered all purposes could easily have been carried on the stationary member. The only really good feature about the fixture is the indexing mechanism which is designed so that it can be operated by a foot pedal.

It is suggested to the student of this book that he make an alternative design of an indexing jig for the same piece of work, employing some of the principles which have been illustrated. The brake drum diameter was 14 in. and the face 3 in.

A decided improvement on the jig shown in Fig. 105 is that illustrated in Fig. 106. A series of six slots containing three holes each, *A*, *B* and *C*, are spaced equally around the periphery of the work *D*. Previous to the drilling operation the work has been bored, turned and faced and a keyway has been cut at *E*. It is necessary to locate the various holes in relation

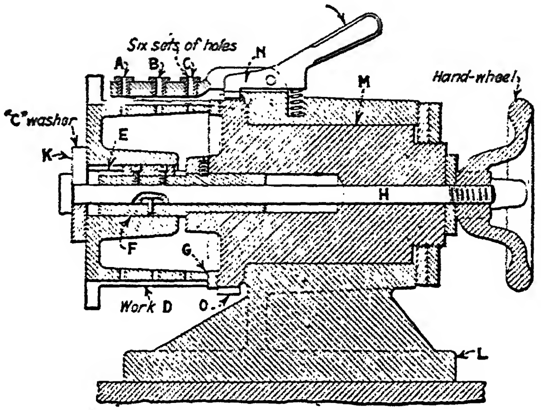


Fig. 106. Indexing Jig for a Clutch Drum

to the keyway mentioned, so the jig is made with a locater to provide for this. The work is slipped over the locating plug *F* and is drawn back against the hardened locating plate *G* by means of the rod *H* operated by the handwheel.

Rapid removal is assisted by means of the C-washer *K*. The base *L* is of substantial construction and has a bearing of large diameter in which the locating member *M* revolves. The correct location of the various holes is obtained by means of the index lever *N* which engages in a series of notches *O* in the outside diameter of the plate. The construction of the lever is somewhat similar to one of those shown in Fig. 98.

In general construction this jig embodies some good features in design and should be studied carefully. Some of the advantages are that it can be cheaply made, and can be easily ad-

justed for wear by simply "papering up" under the locating ring *G* and making suitable adjustments on the bearing *M*.

High Production Indexing Jig.—In Fig. 107 is shown an excellent example of a high production indexing jig for a small hub *A* which has a series of eight small holes drilled radially in its outside diameter. It will be noted that the indexing mechanism is similar to the one illustrated in the earlier part of this chapter. The base of the fixture *B* carries a spindle *C* which is provided with a taper plug *D* so designed that it will expand the split end of the arbor *E* on which the work locates. The

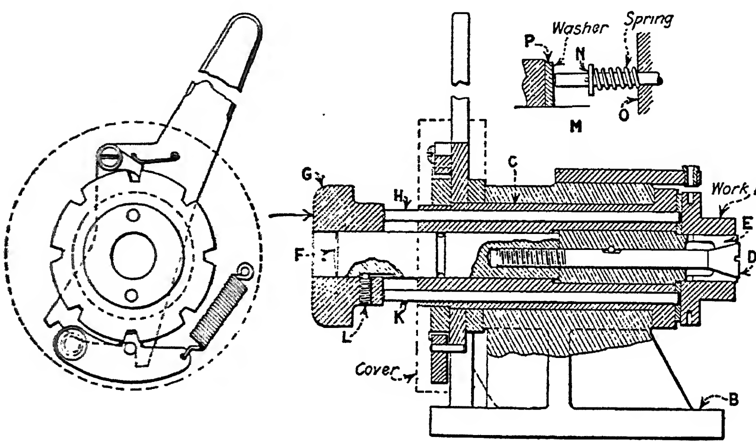


Fig. 107. Rapid Production Indexing Jig for a Small Hub

plug is actuated by the rotation of the threaded plug *F* which is operated by means of the hand knob *G*.

Due to the fact that the work is of a nature making removal from the arbor difficult, the two ejectors *H* and *K* are provided. When the operator loosens the taper plug by means of the knob *G* a slight blow of the hand on the knob in the direction indicated by the arrow will force the work from the arbor. A sliding member is provided for the knob which permits it to act after the screw is tightened to the taper plug. This is done by means of a setscrew *L* which engages with a longitudinal slot in the outside of the plug. An additional refinement can be made on the ejector by using the construction shown at *M*. A coil spring is interposed between the collar *N* and the face *O* so

that it tends to pull the plungers back after they have been operated. A hardened washer also can be fastened against the face of the knob *G* as indicated at *P*. For small work produced in large quantities variations of this design will be found to give excellent results.

Roll-Over Jigs.—A piece of work may require drilling from several sides and it may be of such a size that the jig cannot be handled easily. The conditions may not warrant the use of an indexing or trunnion jig and yet the production required may make it necessary to design a fixture that can be operated conveniently and rapidly. When a jig approaches a size 8 or 10

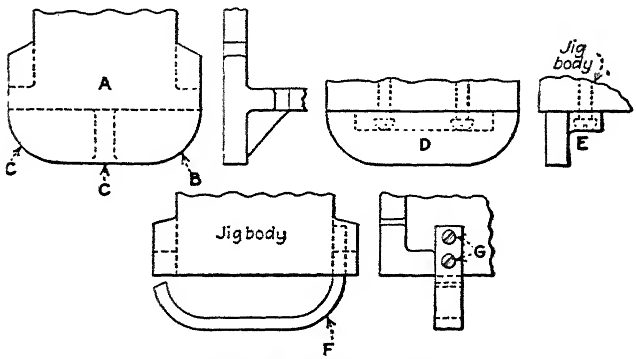


Fig. 108. Designs for Roll-overs

in. square and it is necessary to drill holes from several sides it is often desirable to make provision for rolling over so that the operator will not be obliged to lift the jig or drop it on each side in succession. Several methods of applying "roll-overs" are shown in Fig. 108. *A* is a cast form which is made as a part of the jig itself, the corners *B* and *C* being rounded to permit rolling the jig over on either of these sides. A flat portion is provided at *C* to assist in loading so that the jig will not be wobbling from side to side when the piece is being locked in position.

D shows a roll-over of practically the same form except that it is made as a separate piece which can be applied to the jig body by means of screws *E*. A third form, shown at *F*, is probably the most useful and cheapest of all the varieties illustrated. It is made from a steel strip bent to the shape shown and

screwed to the body of the jig by means of two or more screws *G*. There is very little to be said in regard to the design of roll-overs and the illustrations given are sufficient to cover practically all cases. The points which should be borne in mind are that the roll-over must be so constructed that it will operate easily and at the same time not interfere with any extensions or lugs on the jig or interfere with loading in any way.

In Fig. 109 is shown an outline example of a roll-over jig of simple construction embodying the principles just mentioned The work *A* is located on a central stud *B* and by a nut and C-washer *C*. The requirements of the work are that it must be

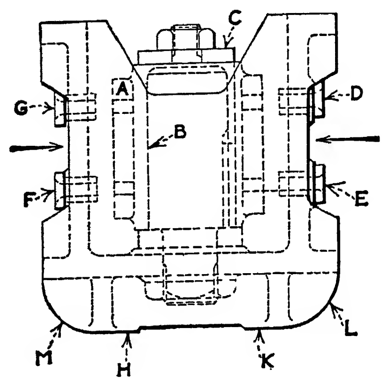


Fig. 109. Roll-over Jig

drilled from the direction indicated by the two arrows. The bushings are shown at *D, E, F* and *G*. When being loaded the jig rests on the table on the flat portions *H* and *K*. It will be seen that it can be readily rolled over on the curved surfaces *L* and *M*.

Design of Trunnion Jigs.—The tool designer should now have a very good idea of jig construction so that he should be able to decide when a trunnion or indexing jig is necessary. We will give here a word of caution in regard to the consideration of the machine capacity on which the trunnion jig is to be used. Be sure to select a machine of sufficient size so that there will be no difficulty in indexing the jig. Another matter which should be thought of is the balance of the trunnion when it is loaded. In all cases the pivot points on which the jig swings should be approximately at the center of gravity of the cradle

when it has been loaded with the work. This brings up another point which should be taken into consideration, namely, the material from which the work is made. For example, large castings may be made of a light metal, such as aluminum, or a heavy metal, such as cast-iron.

In the design of very large trunnion jigs gearing is occasionally used to revolve the work. The gearing is operated by means of a crank which may be either fastened permanently to the fixture or made so that it can be slipped off when not in use.

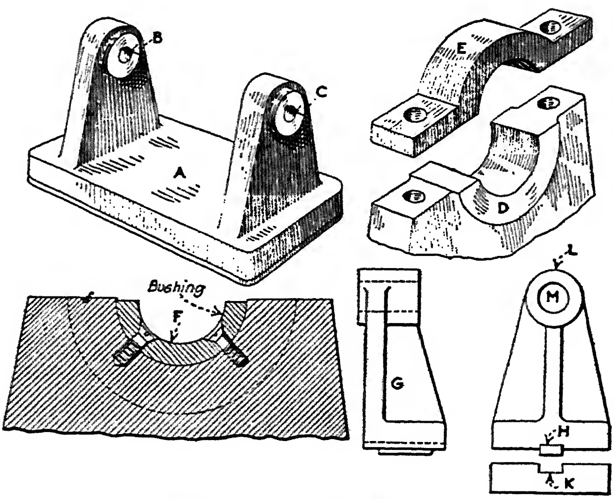


Fig. 110. Trunnion Details

The placing of the work in the jig is an important point that should not be neglected and every provision should be made so that the operator can load the work without a great amount of difficulty.

There are several well-defined types of trunnion jigs as follows: Open or cradle type, in which the work is loaded into a receiving cradle and clamped in place, after which the jig is indexed so that the work can be drilled from the opposite side; closed or box type, in which the work is drilled from several sides in succession; the double trunnion type, a rather uncommon form, built when it is desired to revolve the work in two directions in order to drill it from the ends as well as from the sides.

Details of Trunnions.—In Fig. 110 are shown some details

of trunnions in common use. Form A is a simple type having two trunnion bearings at B and C, the base and the two trunnion bearings being cast in one piece. This type is used where removable plugs act as shafts on which the jig swings. In rare cases the shaft may extend through both holes. The use of this form is limited by the nature of the work and it possesses some disadvantages in that it must be replaced entirely in case any part of it should be broken. It can be used sometimes to advantage where a cheap method of construction is desired. The holes at B and C can be rebored and supplied with bushings when they become worn; or they may be supplied with bushings in the first place which would improve the construction somewhat.

The bearing shown at D is a common form with a cap E. It may be cast iron or furnished with half bushings as indicated at F. The bushings may be made of bronze or steel or they may be babbitted. All bearings on trunnion jigs should be made of generous proportions with plenty of stock allowed for reboring. An excellent way to design trunnion bearings is shown at G. The general form of the bracket indicated can be followed in many cases. Attention is called to the tongue H and the groove K for aligning the two brackets when they are assembled on the base K. In proportioning a bracket of this kind it is well to make the thickness of the hub L not less than half the diameter of the hole M, and it is usually better to exceed these proportions slightly in order to make the construction more reliable and to provide for emergency.

Trunnion Jig with Cradle.—In Fig. 111 is shown a very good example of an open trunnion jig with a cradle. The work A is a large casting which has been previously finished on the side B and is to be drilled from the same side. It would be difficult to load the work in an upside-down position if a plain jig were used. We see here the reason for the trunnion design as it is evident that the work can be readily placed in the cradle and can be clamped by a method similar to that indicated at C. The jig cradle is of cast iron with an index flange at D in which the bushings E and F are located. The trunnion is located so as to distribute the weight of the cradle and the work equally and thus make the indexing easy. The trunnions are supported in bearings F and G, which have removable caps. Following the

procedure shown in Fig. 103 the base G is grooved so that the two brackets carrying the trunnions will be in alignment. An end view of the bracket used is shown at H. The index pin K is of the removable type. It may be attached to the jig with a piece of closet chain. Another form of bracket which can sometimes be used is shown at L. This form is not as strong as that shown at H but for light work it will give satisfaction.

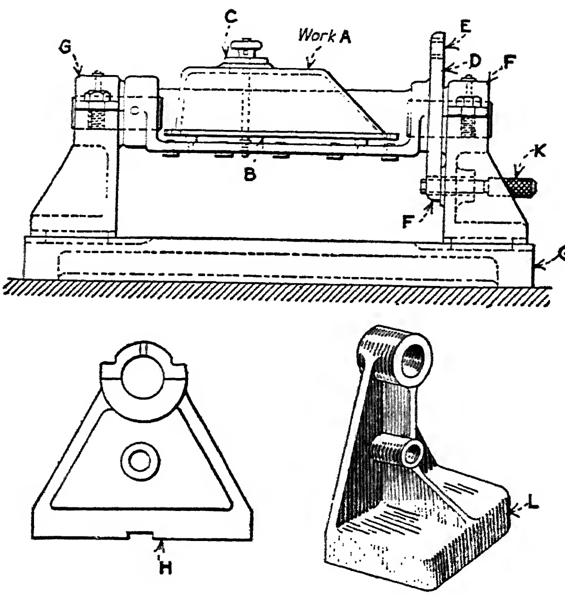


Fig. 111. Open Trunnion Jig with Cradle

The trunnion jig described is very simple, yet of a form which is frequently used. A more elaborate method of indexing can be used if desired.

Trunnion Jig with a Peculiar Index and Clamping Device.—The example shown in Fig. 112 is diagrammatic only and is rather unusual in the principle of indexing and clamping. When drilling the work at A and B considerable pressure would be exerted by the drills at some distance from the center on which the jig is supported and it would ordinarily require a large index plate to give the accuracy required. Assuming that the work can be drilled from two sides only, the indexing portion or box in which the work is held as shown at C can be provided

with hardened and ground parts at *D, E, F* and *G*. These parts must be accurately located in relation to the center *H*.

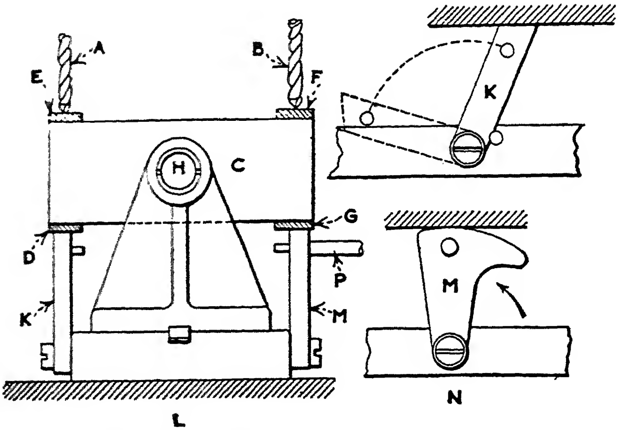


Fig. 112. Unusual Type of Trunnion Jig

At one side of swinging support *K*, shown in detail at *L*, bears against the underside of the hardened plate *D*. On the other

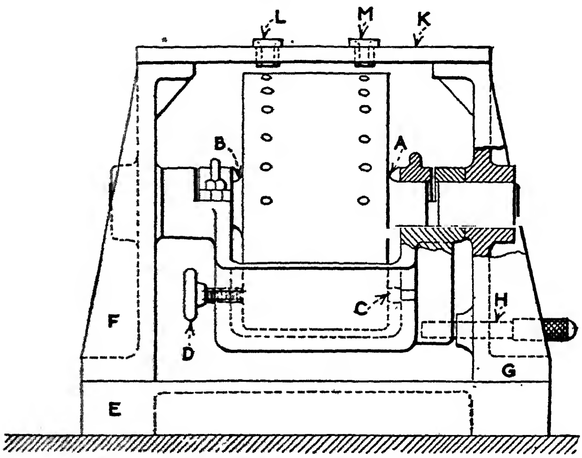


Fig. 113. Trunnion Jig for Cam Drum

side the cam lever *M* is used. When it is desired to index the fixture the two levers *K* and *M* are thrown out of the way. After indexing, support *K* is thrown up into position and the cam lever is operated by means of the handle *P* thus forming an

accurate index and locking the entire mechanism securely. The supporting latches and cams must be of sufficient size to give the necessary stability to the structure.

An example of a good trunnion jig for a large cast-iron drum which has a series of holes half way around the outside is shown in Fig. 113. The work is located by means of the finished hubs *A* and *B*, which rest in bearings as shown and are clamped by means of hinges and leaf clamps. The work is located sidewise

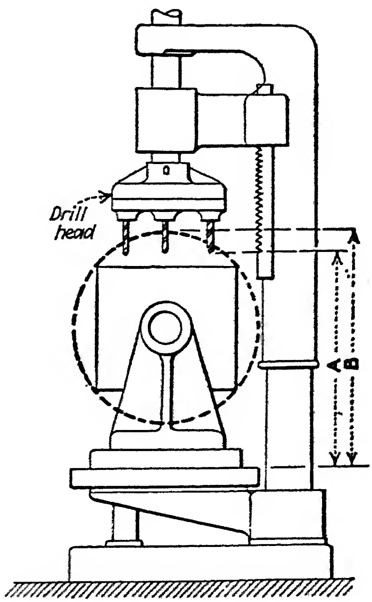


Fig. 114. Trunnion Jig Requiring a Sliding Movement when Indexing

by being forced against the stop *C* by the thumbscrew *D*. The index part of this jig is in the form of a cradle. The base of the casting *E* supports the trunnion brackets *F* and *G*, in the latter of which the index pin *H* is located. A connecting plate *K* carries the two bushings *L* and *M*. In locating the work in the jig the cradle is revolved about 45 deg. from the position shown which permits the work to be rolled into position without difficulty.

Trunnion Jigs Requiring a Sliding Movement when Indexing.—Fig. 114 illustrates the trouble which may be caused by

not carefully considering the machine on which the work is to be produced. When indexing, the jig will follow the path indicated by the dotted circle, which would mean that it would strike the drills. The minimum height above the table to which the drill head can be raised is indicated at *A* while the clearance necessary to swing the jig is shown at *B*.

One method of remedying the difficulty would be to provide a slide that would permit the jig to be moved out into the position shown by the dotted lines. Interference might take place in some other point, for example on the face of the column, in which case the same remedy would prove efficacious.

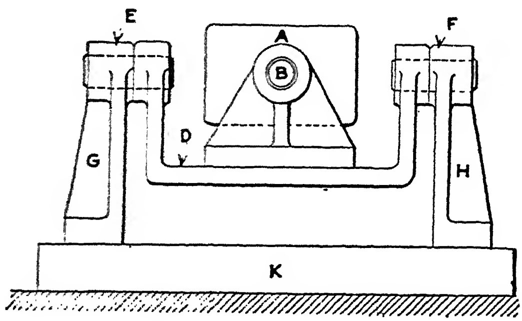


Fig. 115. Principles of Double Trunnion Jig

The diagram shown in Fig. 115 is given in order to illustrate the principles of a double trunnion jig and is not by any means intended to illustrate an actual working jig of this character. The wor_ can be mounted in the indexing member *A*, supported in trunnions at *B* and provided with a suitable indexing device so that it can be swung around in the direction indicated by the arrows. The bracket *C* is mounted on a cradle *D* which in turn is carried by trunnions *E* and *F*. This also is provided with an indexing mechanism in one or the other of the brackets *G* or *H*.

A great deal of care must be taken in the design of a double trunnion jig, but before designing it at all it is well to give a great deal of thought as to whether or 1ot it is advisable to design such a cumbersome mechanism. Generall, speaking it is better to avoid using a device of this kind whenever possible. The principles which have been mentioned in the general de-

scription of trunnion jigs can be applied with equal favor to the double trunnion type, but it must be remembered that there are movements in each direction to take care of, and there is considerable danger of interference when indexing from one position to another. However, there are a number of double trunnion jigs in use here and there throughout the country which have given satisfaction.

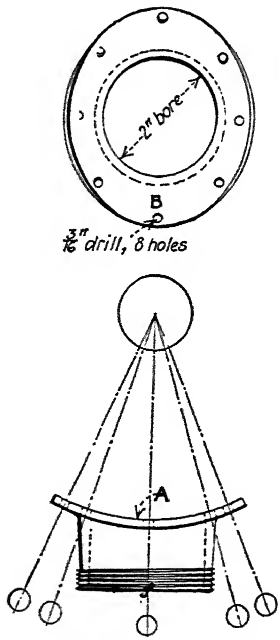


Fig. 116. Example of a Difficult Drilling Problem

A Difficult Drilling Problem.—The work shown at *A* in Fig. 116 is a gasoline tank filler flange which must be drilled with eight 3/16-in. holes *B*. The second view indicates the accuracy required. It is suggested that the tool designer use this example for practice and design a trunnion, cradle or indexing jig in which the various holes can be drilled.

It is a difficult piece of work to handle efficiently and it will serve as a very good brain stimulus to the tool designer. He should be able after a review of the various points and examples given under indexing and trunnion jigs to design a

creditable jig for this piece of work. It is practically impossible to design a roll-over jig or a jig with feet at various angles for this piece of work due to the close approach to each other of the various angles.

A condition frequently found when locating a piece of work which has been previously machined is shown in Fig. 117. The work *A* is located by the outside of the flange *B* in a locating ring *C*. Therefore, if the casting is of large size, it may be difficult to remove the work from the ring after it has been drilled.

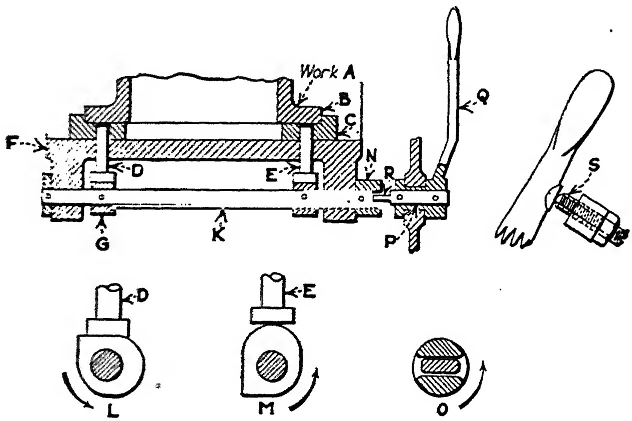


Fig. 117. Ejector for a Large Casting

In order to assist in the removal two pins *D* and *E* are placed opposite each other in the indexing member *F*. These two pins are acted upon by the cams *G* and *H* which are pinned to the shaft *K*. They are locked when in position shown at *L* and take the position shown at *M* when in action.

It will be seen that if the member *F* is the indexing member it is necessary to provide a means of operating the ejectors from outside the swinging member. This is done by pinning a collar *N* to the end of the shaft and cutting a slot across this collar as shown at *O*. The pin *P*, controlled by the lever *Q*, is flatted at *R* so that it loosely fits the slot in the collar *N*. When the jig is indexed this slot and pin will come into alignment so that the pin can be revolved by means of the lever thus raising the ejector pins and forcing the work up out of the seat. A suitable stop such as that indicated at *S* is suggested in order that the

lever may always regain a certain position to make the engagement of the pin with the slot absolute.

Trunnion Jig Used Progressively.—Let us assume that a piece of work, held in the trunnion jig at *A* in Fig. 118, is to be drilled from three sides in sequence. It is possible to mount the trunnion jig on wheels and to provide a track on which the jig can be rolled, so that it will come successively under the

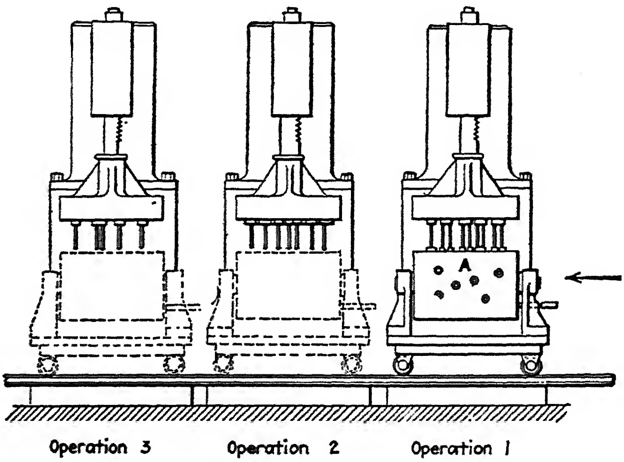


Fig. 118. Trunnion Jig Used Progressively

spindles of the three single spindle machines equipped with multiple heads. It may be found advisable to provide suitable stops for the positions of the jigs. Arrangements of this kind would be made only when high production was desired.

The use of the trunnion jig for progressive machining is very common in the modern automobile shop, however, for drilling cylinder and crankcase castings. Frequently as many as half a dozen different operations are performed on as many machines, the jig passing along the track from one machine to the next as the successive operations are performed.

CHAPTER VI

DETAILS OF MILLING FIXTURE CONSTRUCTION

Types of Milling Machines—Types of Cutters—Important Details in Fixture Construction—Elimination of Lost Time—Elements Necessary in Efficient Tool Designing—Locating Points—Methods of Clamping—Applications of the Lever—Multiple Clamps—Design and Use of the Hook-Bolt—Supporting and Clamping Thin Castings—Principles and Methods of Pneumatic Clamping.

As a factor in high production of interchangeable parts, the milling machine is of the greatest importance. With the exception of the turret lathe and screw machine there is no other machine tool which approaches it in importance to manufacturing. On account of its value as a producer, the fixtures used in connection with it should be of the most up-to-date character and should be so designed as to obtain the greatest efficiency from the machines to which they are applied.

Types of Milling Machines.—In order to understand thoroughly the requirements of milling fixtures, it is necessary first to know the various types of milling machines in order that their adaptability for different classes of work may be fully appreciated. There are a number of forms of machines, among which are hand-milling machines, Lincoln type, plain and universal, duplex, multiple spindle, vertical, continuous and some other varieties more or less specialized either in general mode of operation or in their application to particular kinds of work. Among the latter class are spline milling, profiling, cam cutting, automatic form-milling, rack cutting, gear cutting and hobbing machines. There is also the thread milling machine for milling screw threads and worms. In fact, the process of milling is adapted to so many kinds of work that new machines,

which employ milling as a means for removing stock, are continually being developed to assist in the solution of production problems.

Considered as a machine type, there are more varieties of milling machines on the market than any other machine tool in use to-day. The engine lathe is frequently used in small shops as a milling machine and many horizontal boring mills are arranged so that they can be used for milling as well as for boring. In reality, any machine having a spindle to which a milling cutter can be applied has possibilities in the line of milling, and can be adapted to this kind of work by the use of a sliding fixture arranged to operate at right angles to the spindle.

However, we shall take up the application of milling fixtures to only those types of milling machines that are commonly used for production.

Selection of Machines.—The efficiency of a milling fixture may often be affected by the type of machine on which it is used. Hence it is well to consider the adaptability of the various machines used in milling operations in order that a judicious selection may be made for a given piece of work. In order to familiarize the designer with the adaptability of the various types of milling machines a series of diagrams is given herewith, a reference to which will be of assistance in reaching a decision.

These diagrams are intended to show the particular class of work for which the machines are best adapted, yet it must be remembered that there is no hard and fast rule which will absolutely determine the placing of a certain kind of work on a given type of machine. Many factors have an influence in the matter; for example, a form milling operation may be most suited to a Lincoln type of milling machine, yet on occasion it may be accomplished satisfactorily on a plain milling machine if the Lincoln type machine is not available. So also a key-way may be cut on a hand milling machine or on a plain machine, and a straddle milling operation may be done on a hand milling machine. In the selection of machines, then, the designer must be governed not only by each machine's adaptability to the work in question but also by the machines which are available. In an old factory this matter must be carefully considered, as the

machines are already installed. but in planning operations for a new factory, where new machinery is to be bought, it is im-

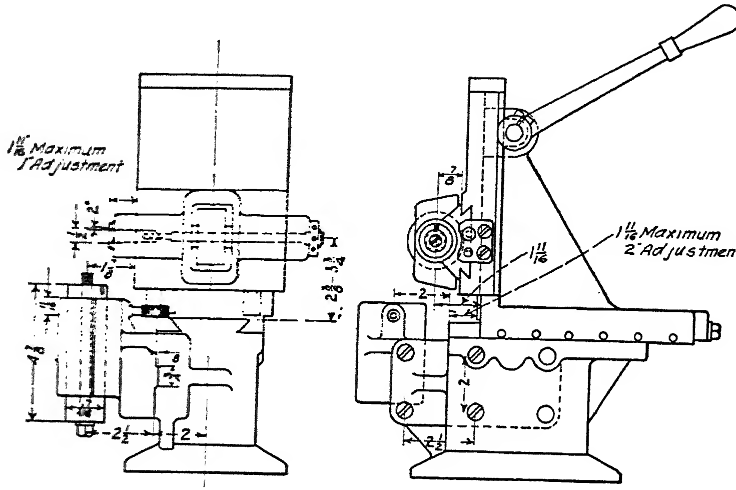


Fig. 119. Type of Bench Milling Machine

portant to select the machine most suited to the work and purchase it.

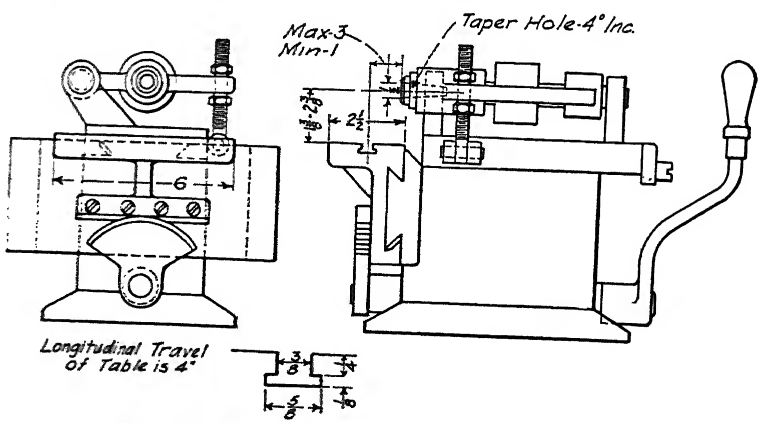


Fig. 120. Another Type of Bench Milling Machine

Bench Milling Machines.—A type of bench milling machine which is very useful for small work is shown in Fig. 119. Machines of this kind are often made and used for production work

of various kinds, and their accuracy and compactness make them very useful when great numbers of small parts are to be milled. The construction of the machine will be clearly understood from the illustration.

Another type of bench milling machine is shown in Fig. 120. The arrangement of this is slightly different from the one previously described, but it serves to show the field of such machines. The feeding mechanism in this case is by means of a hand lever which operates a sector meshing with a rack on the under side of the dovetail slide. Fixtures can be applied to the table, which is provided with a T-slot for convenience.

Hand Milling Machines.—Referring to the diagram at *A* in Fig. 121, two views of a standard type of hand milling machine are shown. Machines of this kind can usually be purchased in two sizes, both of which are driven by an open belt without back gearing. They are usually provided with a two- or three-step cone pulley in order to obtain a suitable range of speeds. In some types the head *B* which carries the spindle is mounted on a vertical slide, so arranged that it can be moved up or down by means of the lever *C*, to which a weight *D* is often attached in order to provide a gravity feed. The table *E* has a cross movement operated by a lever. An over-arm *F* is arranged so that the arbor can be given an outboard support when desired. Another type of hand milling machine has a spindle mounted in a fixed head, the table being arranged so that it can be fed up and down by one lever and crosswise by another. This type is not shown in the diagram, but its construction will be readily understood.

The class of work to which these machines are most suited consists of key-way cutting, slotting, light-facing or forming cuts, light straddle milling operations, or any other light work of a similar character. The machine, not being equipped with back gears, is not suited for any kind of heavy cutting nor is it adaptable to long surface cuts on account of its being a hand feed machine. For work on brass or aluminum parts, which require high surface speeds, this type of machine is a wonderful producer, rapid in operation and economical in upkeep. It is frequently utilized for light facing cuts by using an end mill.

Plain Milling Machines.—The diagram at *G* shows a plain milling machine which is made in a number of sizes suitable

for both light and heavy work. The smaller sizes are sometimes made without back gears while the larger machines are heavily geared and suitable for very heavy cutting. The same general type of machine, when adapted to very heavy cutting, is variously termed a "manufacturing milling machine" or a "heavy duty milling machine," according to the manufacturer's fancy.

In this type of machine the spindle H is tapered at the end

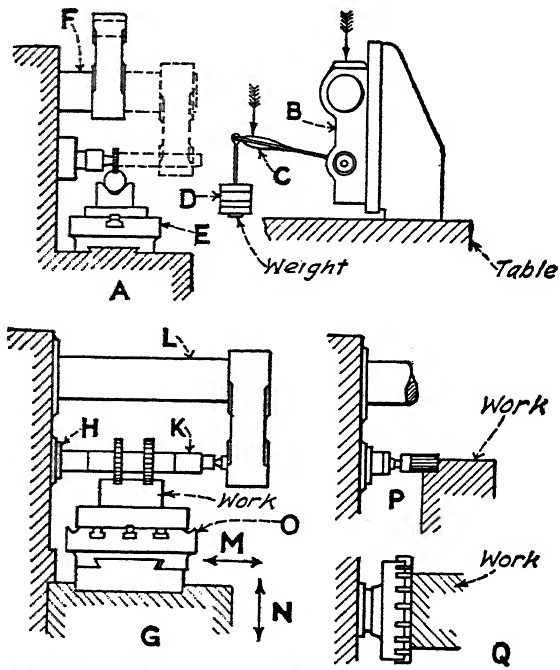


Fig. 121. Hand and Plain Milling Machine Diagrams

to receive the arbor K, and oftentimes a cross slot in the end of the spindle is provided to give additional driving power to the cutter arbor. The over-arm L is adjustable so that it will support the end of the cutter arbor as indicated. Additional arbor supports can be used midway on the over-arm to give additional rigidity for very heavy cutting. The table on machines of this type is arranged so that it has three movements:

1. Adjustment or power feed in and out in the direction indicated by the arrows M.

2. Hand and power feed at right angles to the cutter arbor.

3. Hand and sometimes power feed vertically in the direction of the arrows at *N*.

The table *O* is provided with two or more T-slots used for locating fixtures and clamping work.

Machines of this type are used for slotting, straddle milling, face milling, gang milling, form milling, etc. The larger sizes

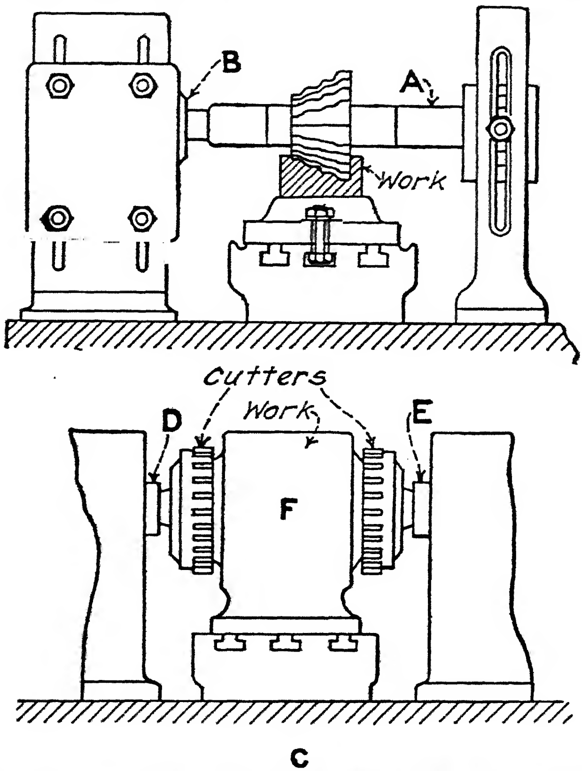


Fig. 122. Lincoln Type and Duplex Milling Machine Diagrams

are chiefly used in manufacturing in connection with milling fixtures for heavy cutting, and can be adapted for many kinds of work. The over-arm can be dispensed with for work when an end mill is used like that shown at *P*. Also a large inserted tooth mill can be applied to face a piece of work as at *Q*.

Lincoln Type of Milling Machine.—One of the oldest forms of milling machines is the Lincoln type, a diagram of which is shown in Fig. 122. This machine is quite different from the

others mentioned, as the table has no vertical adjustment. An adjustment to the spindle permits this to be set vertically within certain limits. Referring to the illustration, the cutter arbor *A* is held by a taper in the end of the spindle *B* and is drawn back tightly by means of a threaded rod passing through to the other end of the spindle. The cutters must be set in relation to the work by means of spacing collars on the cutter arbor *A* except when the table has longitudinal adjustment. Machines of this kind are built in several sizes, all of which are provided with back gears and power feed. They are intended principally for forming cuts, gang milling, heavy straddle milling and slotting. Their general construction adapts them for use on long work of such a character that the cut is continuous from start to finish. Vises with special jaws are frequently used on machines of this kind for military rifle parts, sewing machine parts and many other conditions requiring continuous and formed cuts.

Duplex Milling Machine.—In general manufacturing it is often necessary to face off two or more surfaces on opposite sides of a casting or forging. For conditions of this kind the duplex milling machine, a diagram of which is shown at *C* in Fig. 122, is of great value. Machines of this type are provided with two spindles. *D* and *E*, which are adjustable towards each other and sometimes vertically. Provision is made for heavy cutting by means of back gears in some types, while others are driven by an open belt on a two- or three-step cone pulley. The machines are made in several sizes for both light and heavy work.

The class of work to which machines of this kind are best adapted is shown by the work *F* in the illustration, but in the smaller sizes they are useful for slotting or facing bosses on opposite sides of light castings and other work of a similar nature. Many cases are encountered when work can be done by their assistance which would require two operations on some other type of machine.

Vertical Milling Machines.—Machines having a vertical spindle, adapted to hold milling cutters, are made in several sizes by a number of manufacturers. We are not particularly interested in the various types, as these are much the same in general construction, although some have more refinements and conveniences than others. Generally speaking, the spindle is driven

by means of gearing except in the machines intended for very light work. In some types an accurate vertical adjustment to the spindle with a convenient method of setting makes it possible to mill several heights of work one after the other without disturbing the height of the table during the process. By the use of size blocks and the adjustment mentioned very accurate work can be produced in this way.

Fig. 123 shows a diagram of a vertical milling machine at *A*,

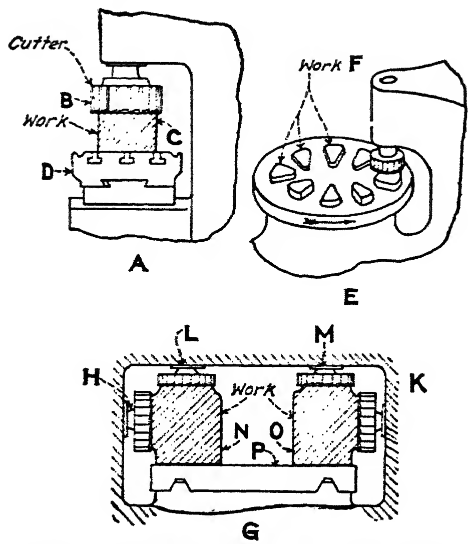


Fig. 123. Vertical, Continuous and Multi Spindle Milling Machines

with a large inserted tooth cutter *B*, in use for surfacing the work *C*. The table *D* is provided with power longitudinal feed and occasionally with power cross and vertical feeds also. Machines are arranged to give a variety of feeds in both directions on some machines, while in others the longitudinal feed to the table is the only one. Adjustments are always provided, however, for raising and lowering the table and moving it in and out. The longitudinal feed is the most used, although the others are occasionally required and are very useful at times.

The work to which these tools are best adapted is the facing of large castings, such as flanges, transmission cases, etc., al-

though in addition to this work they are suitable for cutting shoulders, some kinds of forming, undercutting flanges and many other operations. They can be run at high speed and as a consequence are often used for aluminum and brass work.

Circular Milling Attachments.—The vertical type of milling machine can be supplied with a circular table having power rotary feed, which is useful for continuous or circular milling operations. A diagram showing the application of this attachment is shown at *E* in Fig. 123. The table can be furnished with multiple fixtures to hold a number of pieces which are to be milled. In the case shown the table revolves as indicated by the arrow, and the work *F* is loaded and unloaded by the operator without stopping the machine so that the cutting operation is practically continuous. The economy effected by the use of multiple fixtures of the rotary type is dependent upon the shape of the work to be milled, the method used in setting up the work and the amount of space between the pieces. In other words, as the rotary feed of the table is continuous, the cutter should be producing chips practically all of the time. Consequently it is not profitable to make continuous rotary fixtures for work of such shape that the pieces cannot be set close together or when the cutter will be "cutting air" a good part of the time.

Multiple Spindle Milling Machines.—When one or more spindles of a milling machine are arranged horizontally and others are set vertically, the machines are called "multiple spindle." The common form shown at *G* has two spindles, *H* and *K*, in a horizontal plane and opposite to each other and two additional spindles, *L* and *M*, arranged vertically. The horizontal spindles usually can be adjusted vertically and towards each other within certain limits, while the vertical spindles are provided with both lateral and vertical adjustments. The work, *N* and *O*, can be faced on top and at the sides in the same setting, and fixtures can be so arranged that a number of pieces can be set up so as to make the operation very nearly continuous. The table *P* may be fed by rack and pinion, screw and nut or angular worm and rack, according to the practice of the various machine tool makers. Machines of this type are very powerful, are suited to heavy manufacturing and may have as

many as seven spindles in some cases. The table P is often very long so that it will contain a number of fixtures if desired.

Machines of this kind are generally used for facing the top and sides of castings. They are high production tools for which it is customary to make multiple fixtures holding a number of pieces.

Indexing Milling Machines.—In order to facilitate the milling of certain kinds of work and to make the operation very nearly continuous and thus avoid loss of time both for the operator and the machine, an indexing milling machine has been developed, as shown in outline in Fig. 124. This machine

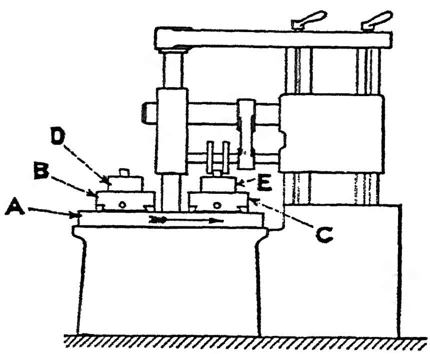


Fig. 124. Indexing Milling Machines

is provided with a rotary table indicated in the diagram at A. On the table two slides are mounted at B and C in such a way that they can be indexed if desired. Assuming that a piece of work shown at D is to be machined, it would be loaded into the fixture in the loading position as indicated in the diagram. While the loading operation is going on another piece of work E is being machined. It will be seen that the only time lost on a machine of this kind is the amount necessary for indexing from one position to the other, so that the operation is very nearly continuous.

The machine is of rigid construction and is provided with feeds suitable for heavy cutting. There are many cases when machines of this kind can be used on straddle milling work, grooving, or surfacing in order to increase production.

It is advisable for the tool designer to provide himself with

data showing various dimensions of importance on milling machines. These diagrams can be made up in a form like that shown in Fig. 125. There is practically all the information given that the tool designer needs when designing a milling fixture for use on this particular type of machine. It is not neces-

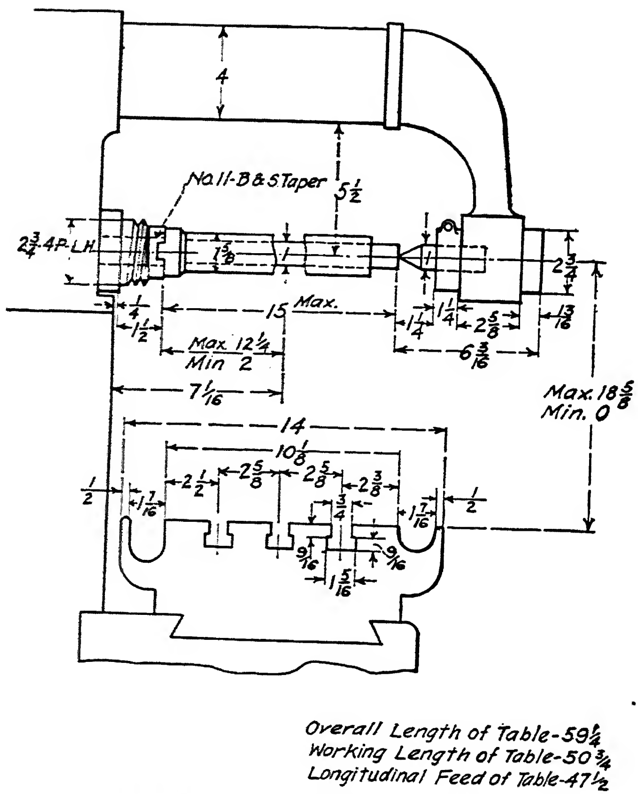


Fig. 125. Diagram of Milling Machine Showing Dimensions Necessary for Designing Fixtures

sary to make diagrams of this kind in great detail, but maximum and minimum dimensions are important, as they show the range of the machine. Dimensions of T-slots and spacing of the same together with table dimensions are important.

Selection of Milling Cutters.—Various kinds of work require cutters of different kinds in order to produce the work to the best advantage. In the selection of these cutters the tool engi-

neer must be governed by the kind of material which is to be cut as well as the form of the cut. Fig. 126 shows a number of milling operations with the cutters most suitable for each particular piece of work. The work *A* is made from steel, and it is

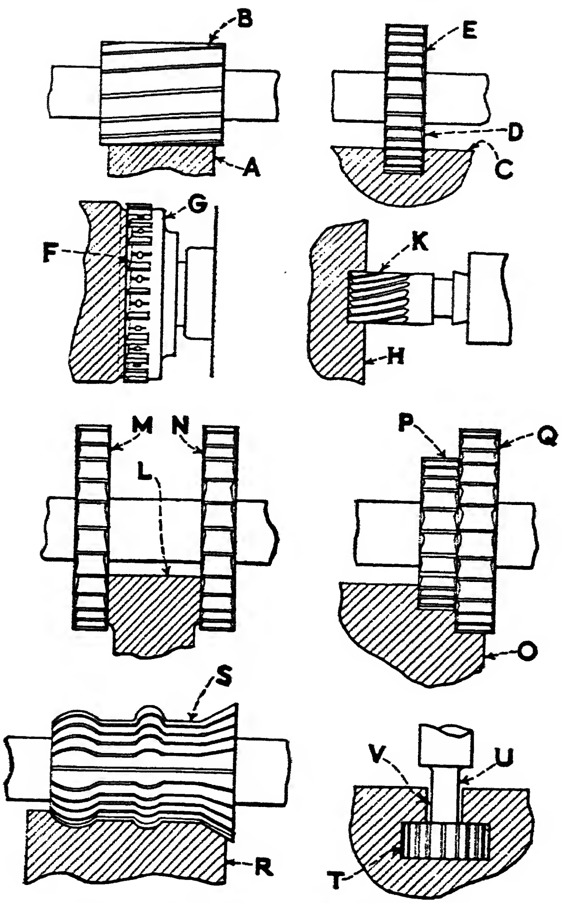


Fig. 126. Application of Milling Cutters

to be surfaced. Assuming it to be a forging, a spiral cutter like that shown at *B* would be suitable for the work. This cutter would have the various teeth nicked alternately in order to "break the chip" if the cut were to be a very heavy one.

The work *C* is of cast-iron and is to be slotted at *D*. For work

of this kind a side milling cutter should be used, such as that indicated at *E*. The work shown at *F* is of cast-iron and is to be faced as indicated. This work, being of large size, can be cut to best advantage with an inserted tooth cutter like that shown at *G*. Another method of milling a slot in cast-iron is shown at *H*. This work might be done by using an end milling cutter *K*. In connection with the use of this type of cutter for machining a slot it is well to note that the cutter should be smaller than the slot which is to be machined, and two cuts would usually be necessary to finish the slot to the required width.

The work shown at *L* may be of cast-iron, bronze, aluminum, or steel, but in any one of these cases the straddle milling cut shown would probably be done by means of the two side milling cutters. *M* and *N*. For the shoulder work shown at *O* two side milling cutters, *P* and *Q*, would be found suitable. It would be necessary to relieve the face of the cutter *Q* so that cutter *P* would lie close against it and slightly within the edge of the teeth on the *Q* cutter.

For forming a piece of work such as that shown at *R* a form milling cutter *S* would be required. Cutters of this kind are so made that they can be ground on the edges of the teeth without losing their form. The T-slot shown at *T* must be machined by what is termed a T-slot cutter as shown at *U*. The slot *V* is machined first by means of a cutter similar to that shown at *K*, after which the T-slot cutter is used.

Other Forms of Milling.—Fig. 127 shows several other varieties of milling cuts for which special machines are used. The work *A* is a shaft in which it is required to cut two splines of the form shown at *B*. These splines must be directly opposite each other and in the center of the shaft. For work of this kind a double head machine with adjustable spindles at *C* and *D* is commonly used. This machine is termed "a spline milling machine." The type shown can be so adjusted that both cutters are working to the same depth, or they can be adjusted so that one cutter is withdrawn while the other continues to cut until it has passed by the center of the shaft being milled. In this way a slot can be readily produced entirely through a given piece of work. Machines of this kind are semi-automatic in their action, the work being reciprocated to a length determined by the length

of the spline, the cutter being fed into the work at the end of each stroke.

Another type of machine for cutting splines is shown at *E*. The work *F* has a single spline cut at *G* which is machined by means of an end mill in the head *H*. This type of machine is

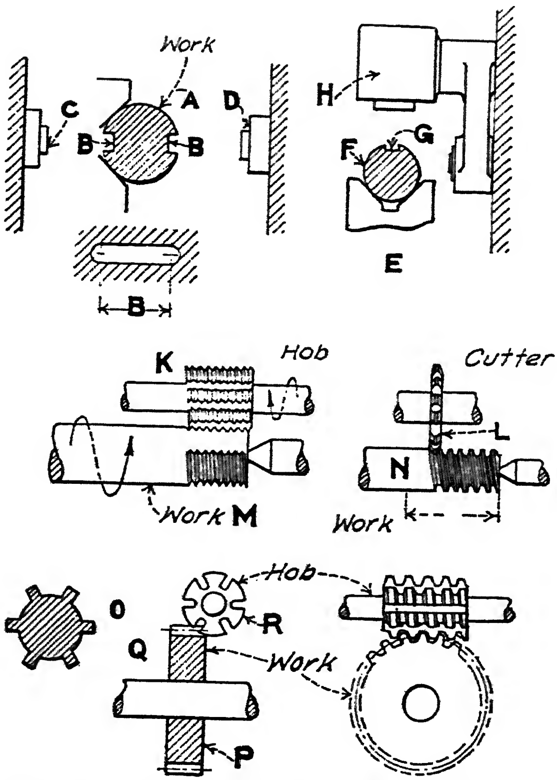


Fig. 127. Special Applications of Milling Cutters

provided with a reciprocating motion and an automatic feed for the cutter at the end of each stroke.

In the production of threaded work a special type called a thread milling machine is frequently used. For some varieties of threads a hob cutter can be used like that shown at *K* while in other cases a single cutter like that at *L* may be utilized. In using the hob cutter one revolution of the work *M* will produce

a completed piece. In the other case the work N would need to be revolved as many times as there are threads.

For very heavy Acme or square threads the thread milling machine is very useful, and it is utilized also for threading shafts such as lead screws. The work obtained by this method is very accurate and uniform in quality.

Spur and spiral gears are often cut on gear cutting machines or gear hobbing machines. Splined shafts like that shown in

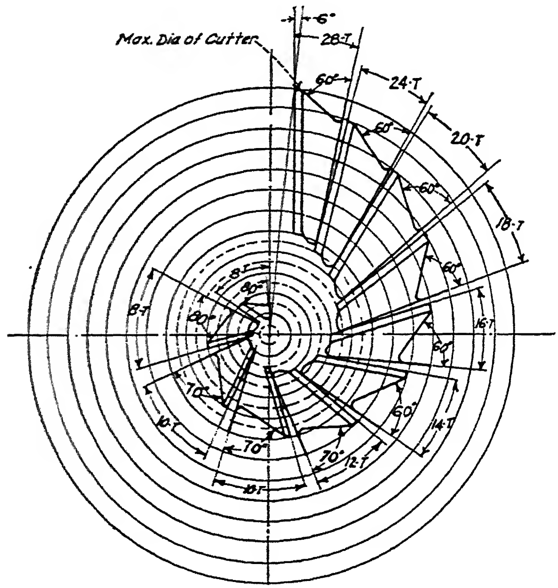
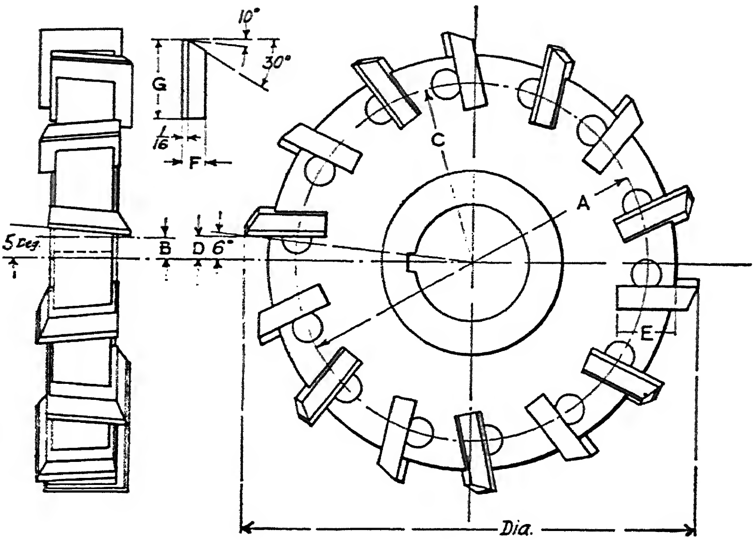


Fig. 128. Contour Cutter Sizing Chart with Teeth Set Off 6 Degrees

the section at O are also made on a hobbing machine of this type. The work P, which is a spur gear, would be mounted on an arbor Q in a gear hobbing machine, and the teeth would be cut by means of a hob as indicated at R. In operation the gear is continually revolving, and the hob cutter gradually passes through one or more gears according to the size and general shape of the blanks. Suitable feeds are provided, and the machine is also furnished with a knock-off which can be set so that the machine will be stopped after the work is finished.

There are many other milling machines of more or less specialized forms, some of which are used in the manufacturing of

certain kinds of work. As these machines are so highly specialized, it is not advisable to attempt a description of them because they are seldom required by the tool engineer when working out production problems.

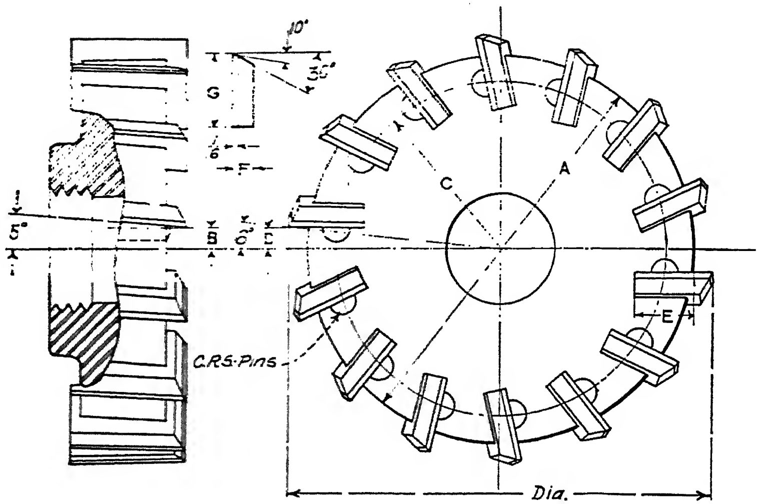


Dia. of Cutter	No. of Teeth	A	B	C	D	E	F	G	Dia. of Pins
5	14	4½	.156	1 15/16	.261	5/8	1/4	7/8	5/16
6	16	5½	.209	2 7/16	.314	5/8	1/4	7/8	5/16
7	18	6½	.230	2 7/8	.366	3/4	5/16	1	3/8
8	20	7½	.282	3 3/8	.418	3/4	5/16	1	3/8
9	22	8 3/8	.334	3 27/32	.470	3/4	5/16	1	3/8
10	24	9 3/8	.355	4 9/32	.523	13/16	3/8	1 1/8	7/16
11	26	10 3/8	.408	4 25/32	.575	13/16	3/8	1 1/8	7/16
12	28	11 3/8	.460	5 9/32	.627	13/16	3/8	1 1/8	7/16

Fig. 129. Inserted Tooth Milling Cutter with Staggered Blades

Cutter Sizing Chart.—A contour cutter sizing chart is shown in Fig. 128. This chart is convenient for use in designing milling cutters. The number of teeth varies according to the diameter of the cutter, and in this example all teeth are set off 6 deg. Variations can be made to suit conditions, but the chart in itself will be found useful as a guide in obtaining properly proportioned cutters.

Fig. 129 shows a chart for inserted tooth milling cutters having staggered blades. In this example the blades are set over alternately as indicated. This makes it useful in sizing a slot or something of this sort. The various dimensions given will be found useful in proportioning cutters of this kind.



Dia. of Cutter	No. of Teeth	A	B	C	D	E	F	G	Dia. of Pins
6	16	5 1/2	To Suit	2 7/16	.314	5/8	1/4	7/8	5/16
7	18	6 1/2	To Suit	2 7/8	.366	3/4	5/16	1	3/8
8	20	7 1/2	To Suit	3 3/8	.418	3/4	5/16	1	3/8
9	22	8 3/8	To Suit	3 27/32	.470	3/4	5/16	1	3/8
10	24	9 3/8	To Suit	4 9/32	.523	13/16	3/8	1 1/8	7/16
11	26	10 3/8	To Suit	4 25/32	.575	13/16	3/8	1 1/8	7/16
12	28	11 3/8	To Suit	5 9/32	.627	13/16	3/8	1 1/8	7/16

Fig. 130. Inserted Tooth Milling Cutter with Solid Body

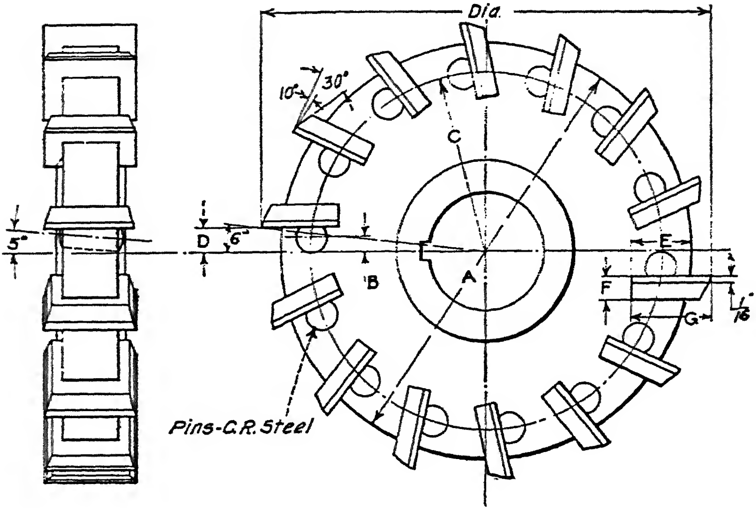
Fig. 130 shows another type of inserted tooth milling cutter made with a solid body as shown. This type of cutter is designed primarily for face milling, and the body screws directly on to the spindle. The proportions and various dimensions given will be found useful in proportioning cutters of this kind.

Fig. 131 shows a chart of straight side inserted tooth milling cutters. This type of cutter is designed for use on an arbor.

Fig. 132 shows another type of inserted tooth cutter designed

for face milling. This can be made up in solid form as shown and applied to the spindle in some convenient manner. The blades are set at an angle in this example.

Important Points in Design of Milling Fixtures.—In the



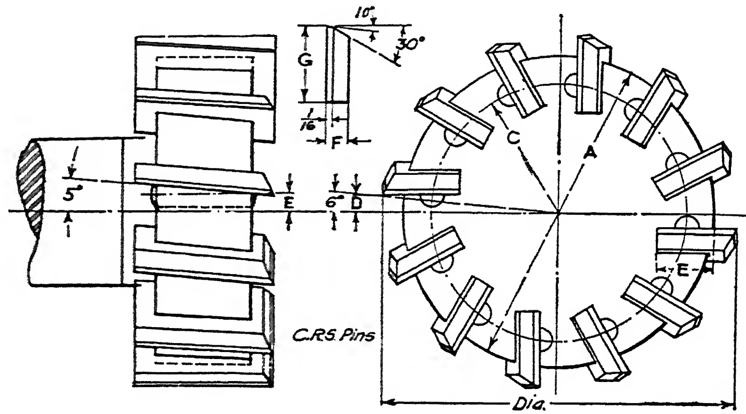
Dia. of Cutter	No. of Teeth	A	B	C	D	E	F	G	Dia. of Pins
5	14	4 1/2	.136	1 15/16	.261	5/8	1/4	7/8	5/16
6	16	5 1/2	.189	2 7/16	.314	5/8	1/4	7/8	5/16
7	18	6 1/2	.210	2 7/8	.366	3/4	5/16	1	3/8
8	20	7 1/2	.262	3 3/8	.418	3/4	5/16	1	3/8
9	22	8 3/8	.314	3 27/32	.470	3/4	5/16	1	3/8
10	24	9 3/8	.335	4 9/32	.523	13/16	3/8	1 1/8	7/16
11	26	10 3/8	.388	4 25/32	.575	13/16	3/8	1 1/8	7/16
12	28	11 3/8	.440	5 9/32	.627	13/16	3/8	1 1/8	7/16

Fig. 131. Standard Straight Side Inserted Tooth Milling Cutters

design and construction of milling fixtures, the following points should be carefully considered:

1. Production Required.—This is an important factor, as the number of pieces to be machined should influence the design of the fixture to a great extent. Simple fixtures should be made for work which is machined only in small quantities, while for high production work the best type of fixture should be designed.

2. *Dead Time on the Machine.*—In analyzing a production problem in which the milling machine is to be used, the dead time on the milling machine should be reduced to a minimum in order to obtain the maximum efficiency of the machine. The milling fixtures should be so designed that there is as little time lost as possible during the loading and unloading of the fixture. In very high production work it is frequently desirable to make up



Dia. of Cutter	No. of Teeth	A	B	C	D	E	F	G	Dia. of Pins
2½	8	2⅛	To Suit	13/16	.131	½	¼	¾	¼
3	10	2½	To Suit	1	.158	½	¼	¾	¼
3½	10	3	To Suit	1¼	.184	½	¼	¾	¼
4	12	3½	To Suit	1 7/16	.210	½	¼	7/8	¼
4½	12	4	To Suit	1 11/16	.236	½	¼	7/8	¼
5	14	4½	To Suit	1 15/16	.263	5/8	¼	7/8	5/16

Fig. 132. Standard Inserted Tooth Face Mills

fixtures that permit one piece of work to be inserted and clamped while the other is being machined.

3. *Accuracy Required.*—When work is to be milled within a tolerance of 0.001 in., it is frequently necessary to make provision for both roughing and finishing cuts. As a rule two fixtures should be made for work of this kind, each one being provided with suitable set blocks for setting the cutters to the required sizes.

4. *Rigidity of Fixtures.*—There is no operation in manufacturing in which *rigidity* is as important as in milling. Weak-

ness tends to develop "chatter," which is injurious both to the cutters and to the machine. Care must be taken in the design of milling fixtures to make sure that there are no weak points and that all portions are well ribbed to withstand cutting strains.

5. *Safety of the Operator.*—The importance of designing milling fixtures so that the operator will not be endangered during the process of loading and unloading the work cannot be over-emphasized. The operator's hands should not approach the cutters closely. The position which the operator is required to take when using the fixture must be studied so that there is no chance for injury due to lack of attention.

6. *Chips.*—As the milling machine is a great producer of chips, attention should be paid to the cleaning of the fixture, and clamps, locating surfaces, and other important parts should be so designed that chips will not interfere with their proper functioning.

7. *Set Blocks.*—All milling fixtures should be provided with set blocks so arranged that the cutters can be set in correct relation to the work. A size block or "feeler" can be interposed between the cutter and the set block when making adjustments. If all fixtures for milling are provided with set blocks the accuracy of the work is assured, and resetting after grinding the cutters is very easily done.

8. *Selection of Machines.*—The selection of the machine best suited to work requires judgment, knowledge of conditions, and a list of machines which may be used, as well as an understanding of the best type of machine for the work in the event that new tools are be purchased. Although the choice of machines may be limited, the selection should always be made with a view to economy in production.

9. *Upkeep of Fixtures.*—Fixtures for high production work should be so designed that replacement of locating parts, studs, clamps and other parts can be readily made. It is very necessary to provide a suitable method of fastening the various units to the fixture in order to facilitate their removal and replacement when worn.

10. *Material To Be Cut.*—The kind of material to be machined affects the design of the fixture to some extent, due to the fact that cast-iron or other cast work such as aluminum and brass can usually be cut faster than such material as alloy

steel. Therefore, the kind of material and the speed and feed at which the job will run have to be considered in planning milling fixtures.

Cutter Action on the Work.—A piece of work being milled is subject to two forces, viz., the feed and the cutting action. The combined result of these two forces tends to move the work out of its position, hence it must be resisted by the fixture and the clamps which hold the work. Due consideration must there-

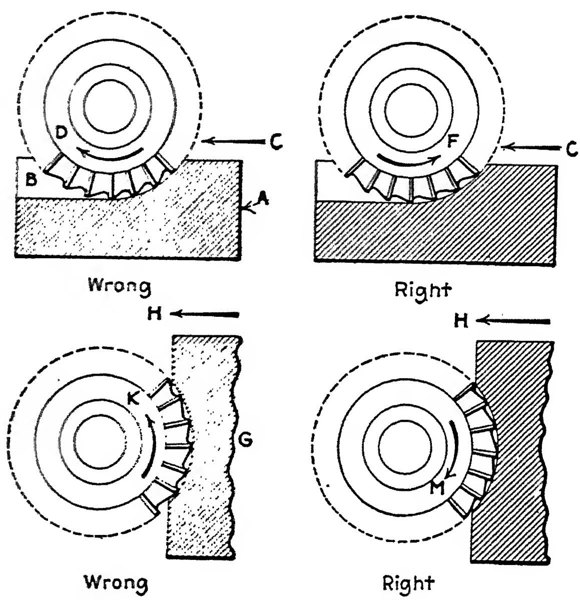


Fig. 133. Diagrams Illustrating Cutter Action

fore be given to the manner in which the work is held in relation to the feed and also to the cutter.

Fig. 133 shows a piece of work at *A* in which a slot *B* is being machined. The feed of the table is in the direction of the arrow *C*, while the cutter revolves as shown by the arrow *D*. The action of the cutter tends to pull the work toward it, which is very bad practice for the reason that any lost motion in the feed screw of the table will cause "chatter" in the work; also the work tends to "crowd" into the cutter teeth so that the cutting action is not good. When the work is fed in the same

direction *C* with the cutter revolving in the direction *F*, there is no "chatter" and the teeth of the cutter attack the work in the proper manner.

The work *G* is being fed in the direction of the arrow *H*, while

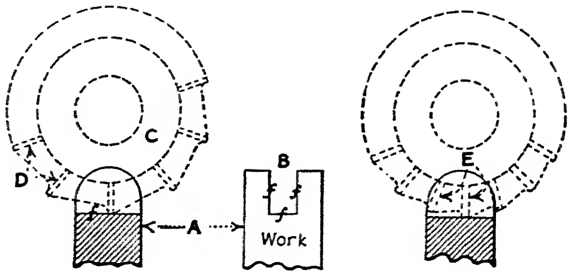


Fig. 134. Action of Cutter Teeth

the cutter is revolving as at *K*. This is incorrect because the cutter action tends to lift the work and may therefore be acting against the clamps which hold it down on the fixture. It may even lift the table itself unless the gibs are adjusted tightly.

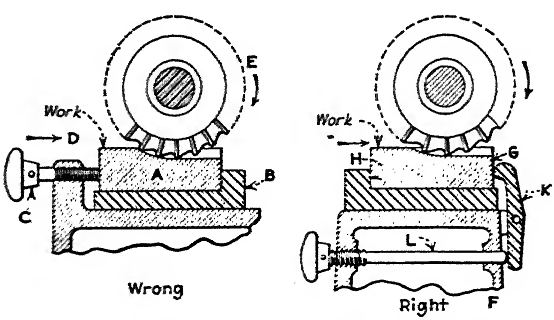


Fig. 135. Cutter Action in Relation to Clamps

When the cutter is revolving in the direction *M*, the pressure of the cut is resisted by the stability of both the fixture and the table.

Fig. 134 shows a lug *A* which is to be slotted as indicated at *B*. Unless care is used in the selection of the cutter, a condition like that shown in the cutter *C* may be found. This cutter has teeth *D* spaced so far apart that not more than one tooth

is in action on the work at the same time. If the feed is coarse, considerable "chatter" and poor work may result.

It is much better to select a cutter having teeth spaced closer together as indicated at *E*, so that there will be several teeth in action on the work at the same time.

In designing milling fixtures it is not generally considered

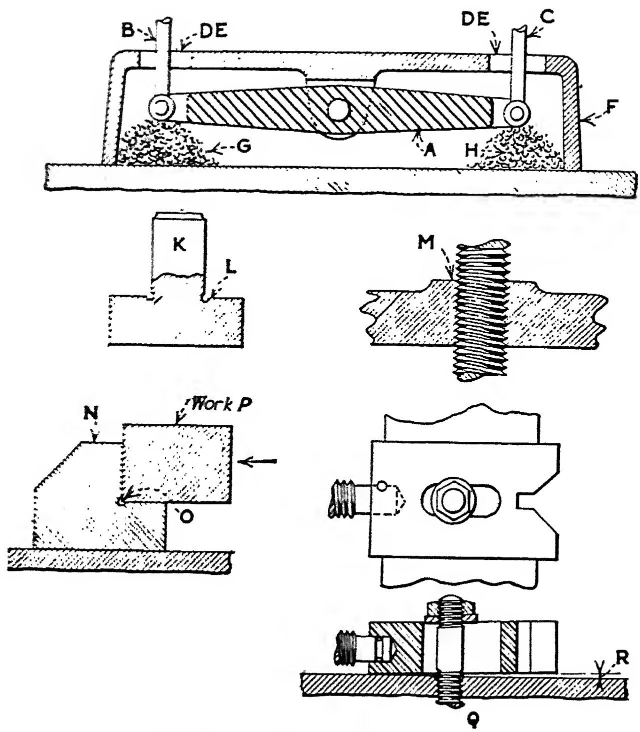


Fig. 136. Trouble Caused by Chips

good practice to clamp the work in such a way that the cutting action is against the clamp. Fig. 135 shows the work *A* held in a fixture *B*, by means of a clamp screw *C*. The direction of the feed *D* and the rotation of the cutter *E* both force the work against the clamp screw. This is very bad indeed and should be avoided.

At *F* the work *G* is firmly clamped against a solid shoulder of the fixture *H* by means of a rocking clamp *K* operated through

the threaded rod *L*. The thrust of the cut is then taken by a solid wall of metal and there is no possibility of "chatter."

Provision for Chips.—Milling cutters produce chips very rapidly and in large quantities. Therefore milling fixtures should be designed so that locating surfaces, clamps, screws and other devices will not become clogged with chips so as to interfere with their proper working. Fig. 136 shows an equalizing lever *A*, connected to two rods *B* and *C* which pass through the holes *D* and *E* in the body of the milling fixture *F*. The openings around the rods permit chips to fall through and accumulate at *G* and *H*, resulting eventually in interference with the action of the levers. The holes should be covered in order to prevent this accumulation or else the fixture should be arranged so that it can be readily cleaned. As a milling fixture is always bolted down to the table in a fixed position, provision for cleaning should not necessitate its removal from the table. Openings in the side of the fixture can be made but it is better to prevent the chips from entering and thus do away with the necessity for cleaning.

At *K* is shown a locating stud with a groove at *I* into which chips or dirt may drop so that work located on the plug will seat itself properly. This is very bad indeed as after a time the groove fills up with chips and dirt which have to be cleaned out frequently to allow the work to locate properly. *M* is an adjustable, threaded member in a fixture base. This also should be avoided as far as possible because chips will eventually work into the thread and make it difficult to operate.

The locating block *N* is relieved at *O* in order to ensure correct location of the work *P*. This design is open to the same objections as the example *K*.

The type of adjustable V-block shown at *Q* is most annoying to an operator, as the chips get in to the elongated slot and also under the block causing it to rise as shown at *R*.

Design of Milling Fixtures.—There is some difference of opinion as to whether a well-ribbed milling fixture will give as satisfactory results as one which is made of very heavy section cast iron without ribbing. Those advocating heavy sections without ribbing claim that the solidity of the metal in a heavy milling fixture tends to lessen vibration and thus give better results than a ribbed milling fixture. The writers believe that

a well-ribbed milling fixture of substantial section will answer the purpose in nearly all cases although for extremely heavy cuts a good body of metal is desirable.

Fig. 137 shows at *A* a solid base plate of cast iron on which a built up fixture can be placed. The illustration *B* shows a similar, though heavier plate. The latter would be better designed as shown at *C*, with the mass of metal reduced and the sections strengthened by the use of ribbing. The view at *D* indicates the position of the various ribs. The ribs of a fixture

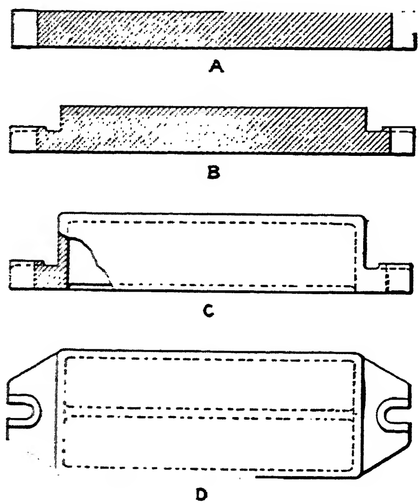


Fig. 137. Design of Fixture Bases

of this type should be so proportioned that there will be no tendency to "buckle" and thus cause vibration while a cut is in progress.

Details of Construction.—Fig. 138 shows a corner wall *A* which has been made to a large radius in order to give maximum strength. Square corners on castings and sections of unequal thickness should be avoided. *B* shows a square corner which is likely to crack at the points shown, due to strains set up by unequal cooling in the foundry.

The diagram at *C* is given in order to emphasize the fact that all castings should be so designed as to allow for "draft." Draft is not necessary to the casting, but the pattern has to be tapered

so that after the mold is made, the pattern can be removed from the sand without injuring the mold. And as the pattern is a duplicate of the casting, the necessary draft is included in the design of the casting. The amount of draft necessary varies from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. per foot. It is advisable to show the draft on deep castings as indicated at *D* and *E*.

Where bosses are provided on castings it is well to make them larger in diameter than appears necessary, in order that the

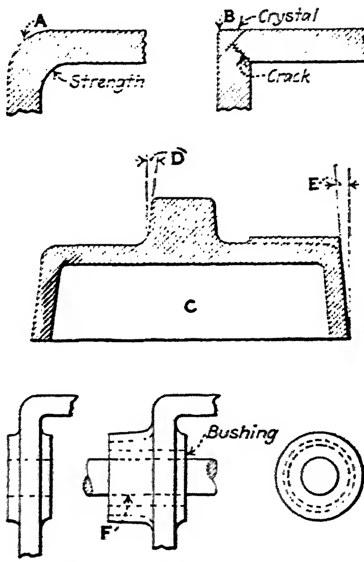


Fig. 138. Details of Construction

location of holes in the bosses may not be seriously affected by variations in the casting. Also when bosses are used as bearings, it is advisable to make them large enough so that they may be bushed for wear as indicated at *F*. There is nothing much more annoying to a toolmaker than to find insufficient allowance for stock on a boss, so that the hole is not central with the boss, allowing a shouldered stud to lap over the edge.

Uniformity of Ribs and Walls.—In order that the castings used for fixture work may be substantial and not subject to cracks due to unequal cooling, uniformity in the sections should be preserved as far as possible. Fig. 139 shows a section *A* in

which the walls *B*, *C*, *D*, *E* and *F* are all of uniform thickness. A fixture designed in this manner will be free from defects or cracks in the metal which are often caused by unequal cooling.

The correct design of ribs is an item which should be given the most careful attention. It is not uncommon to see an angular rib like that shown at *G* when there is no good reason for making it so light. A rib like that shown at *H* will withstand pressure very much better than the other one.

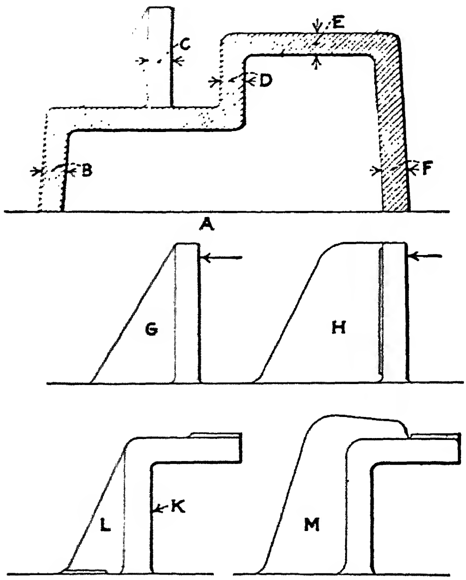


Fig. 139. Uniformity of Ribs and Walls

In the case shown at *K*, the rib *L* has very little value; yet if it were to be made as at *M* it would give stability to the construction and add to the general rigidity of the fixture.

U-Lug Design.—A milling fixture must be bolted to the table on which it is used, therefore a means of fastening must be provided so that it can be quickly adjusted when removing or replacing it. In Fig. 140, *A* shows a good construction for U-lugs. Lugs made to the outline shown by the dotted line at *B* develop a very weak section at *C*. By designing the lugs as indicated by the full lines at *D* and *E*, greater strength is obtained and there is less likelihood of breakage. U-lugs are

usually cored at *F* and the cored dimensions should be not less than 1/16 larger than the T-bolt used to hold the fixture down. A key slot *G* is provided for locating the fixture on the table.

In proportioning the outlines of the boss *H*, it is well to make

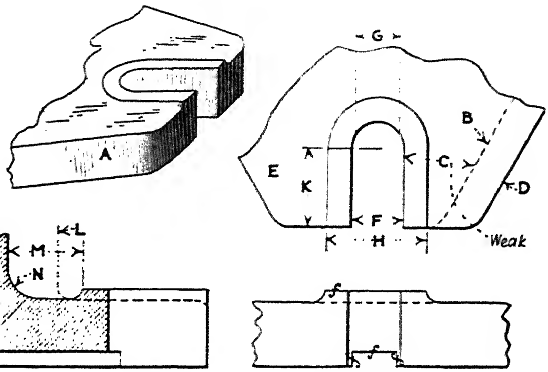


Fig. 140. U-Lug Design

each side of the finished portion at least one-half the distance *F* and even more than this is not objectionable. The depth *K* should always be from one and one-half to two times the dimension *F*.

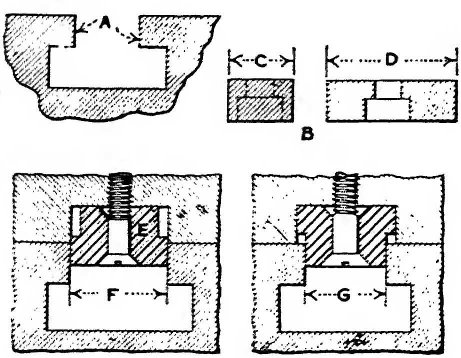


Fig. 141. T-Slots and Keys

U-lugs should not be set in too close to the body of the fixture as indicated by the dotted lines at *L*. It is much better construction to make the distance *M* at least as much as the dimension *F*. When this is done a large fillet can be used at *N* thus giving additional strength to the fixture.

T-Slots and Keys.—Milling fixtures are located on the tables of milling machines by means of rectangular keys which fit the T-slot *A* in Fig. 141. A common form of key is shown at *B*. The dimension *C* is made to the size of the slot in the milling machine table. The length of the key *D* is generally from 2 to 3 times its width.

As milling machine table slots vary from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. with intermediate sizes, it is often desirable to make fixtures transfera-

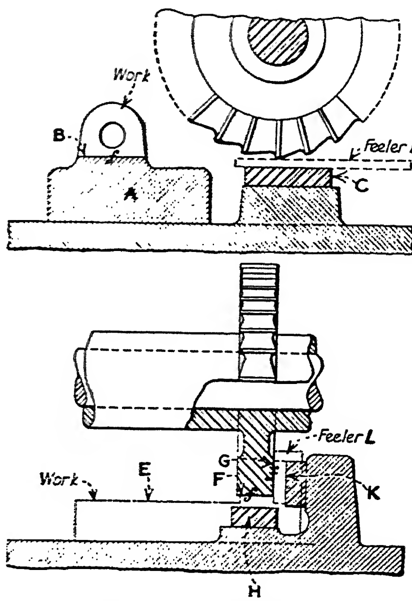


Fig. 142. Set Blocks

ble from one machine to another. To provide for such a condition, the keys can be made as shown in the illustration at *E*. This type of key is so proportioned that it can be used to fit a slot having a width as shown at *F* and it can also be reversed and used to fit another slot like that indicated at *G*. An arrangement of this kind is of great advantage where a number of milling machines having different size slots are to be used in production.

Set-blocks.—In order to make sure that cutters are set in the correct relation to the work on a milling fixture, it is essential that each fixture be provided with suitable set blocks.

Assuming that the work *A* shown in Fig. 142 is to be machined at *B*, a hardened set block *C* should be provided. In setting the cutter to the correct depth a "feeler" *D* is interposed between the cutter and the set block *C*. The thickness of "feeler" can be standardized and suitable allowance made between the top of the set block *C* and the depth of the cut desired.

In the example *E* the work is to be finished on the surfaces *F* and *G* and it is, therefore, necessary to provide set blocks at *H* and *K* so that the feeler *L* can be interposed as indicated in order that the cutter may be accurately set, both vertically and horizontally.

In considering methods used in the location of work in milling fixtures, attention must be paid not only to the position of the locating surfaces, but also to their accessibility for the purpose of cleaning. In addition to these points the thrust of the cutters and their action on the work must also be given considerable attention so that proper provision will be made for resisting this action.

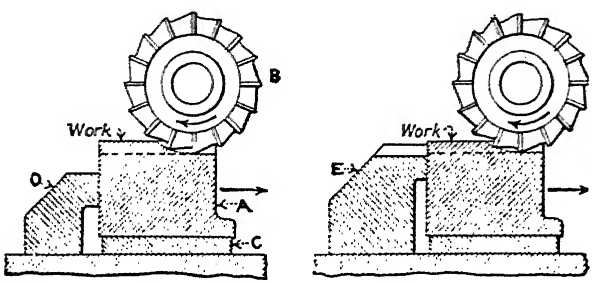


Fig. 143. Methods of Bracing Work

Fig. 143 shows a piece of work *A* which is being fed in the direction denoted by the arrow against the milling cutter *B* which is revolving as indicated. The work locates on a plate *C* and against a block *D* but it will be noted that the portion which is being cut lies in a plane considerably above the block *D* which takes the thrust. This is not good practice and much better results would be obtained by making the block as shown at *E*. Here the work is supported directly in line with the thrust of the cutter.

Locating and Supporting Work.—It is often necessary to locate a piece of work from a finished surface such as that shown at *A* in Fig. 144, and also by means of a hole in the same plane but higher up as shown at *B*. When a condition like this is found it is essential to provide a "float" to one member or the other in order to take care of slight inaccuracies in machining. In the particular case shown the work locates on a central stud

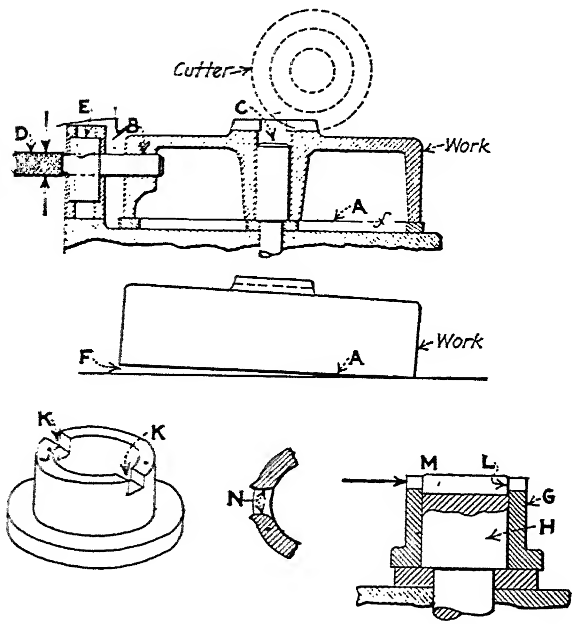


Fig. 144. Locating and Supporting Work

C, on the plate *A*, and by means of a plug *D* mounted in a vertical slide *E*.

If no provision were made for errors in machining it might easily be possible to set up the work and obtain a result similar to that shown at *F* in which the work locates on the plug but does not seat itself properly on the plate at *A*. As cases of this kind are frequent, provision should be made for variations either in the manner shown or by some other means equally good.

The work *G* is a thin collar mounted on a locating stud *H* in order to mill the slot across the top as indicated at *K*. It is very easy to support the work while milling so that the slot on

the side at L will be backed up well, but the opposite side M will have a tendency to open up when the cutter machines it, with a result like that shown at N. The designer should always bear this in mind when making a fixture for a similar piece of work and should provide support at the points where the cutter finishes its work.

Clamps Used in Milling.—In the chapter on the design of drill jigs, various clamps are shown which are used to some extent in all kinds of fixtures. Exceptional cases may require slightly different methods of clamping due to the requirements

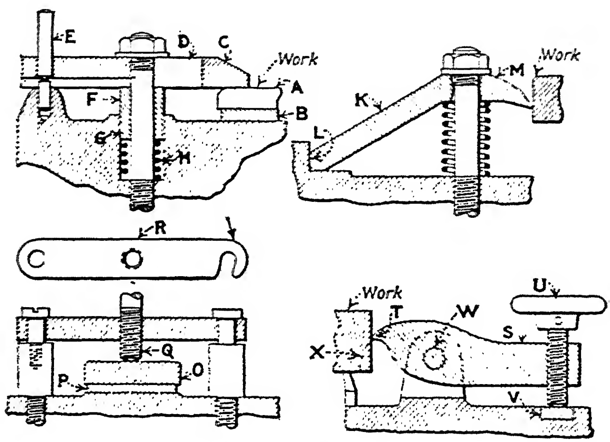


Fig. 145. Various Types of Milling-Clamps

of the work. The method of holding a piece of work for a milling operation is one of the most important things in connection with the design of the fixture, and as a consequence the clamps should be very substantial and should be applied at the proper points in order to obtain the best results.

Several varieties of clamps are shown in Fig. 145. The work A is located on a hardened plate B and is clamped down by means of the strap clamp shown at C. This clamp is slotted at D to permit its being withdrawn from the work by means of the pin E which acts as a handle. A slotted clamp of this sort is likely to become clogged with chips and, therefore, a suitable cover should be placed over the slot. A bushing F can be made so that it fills the hole G occupied by the spring H thus pre-

venting the chips from accumulating around the spring and interfering with its action.

The clamp K is used for holding the work down when a clamp on the top of the work would interfere with a cutter used on the entire upper surface. This type of clamp thrusts against a solid shoulder L and the action of it in clamping tends to sink the point M into the edge of the work and at the same time hold it down. It is advisable to make the point M rather "stubby" so that it will not become dulled too easily. A clamp of this kind is useful when it is difficult to clamp the work in the ordinary way. It is possible to adapt it to a number of conditions to suit particular cases.

A swinging leaf clamp can be used to advantage in holding a piece of work such as that shown at O. The work locates on a hardened plate P and is clamped by means of the screw Q which is held in a swinging clamp R. A leaf-type of clamp is sometimes found necessary in milling fixture design and the principle shown here can be applied if needed.

A rather peculiar type of clamp for work which cannot be clamped in the regular way, is shown at S. This clamp has a knife-edge at T which sinks into the work and at the same time clamps it down. The thumbscrew U has a wear plate under the point as shown at V. It is of the greatest importance in designing a clamp of this sort that the pivot W be located considerably lower than the point T so that the clamping action will be *down* in the direction indicated by the radial line X.

Special Forms of Clamps.—Work of peculiar or irregular shape which has not been provided with clamping lugs often calls for the design of special clamps in order to hold it properly and without distortion or dislocation. Considerable ingenuity is sometimes required in order to devise a suitable method. A number of clamps designed to suit peculiar conditions of holding, are shown in Fig. 146. The casting A has an overhanging flange C which is to be machined as indicated by the f mark. The work rests on locating plugs, one of which is shown at B. The ordinary type of clamp would be difficult of access if used for a condition of this kind, therefore a device must be used which will give satisfactory results and which will be readily accessible. Several methods are shown which may be adapted to work of this kind.

The clamp *D* is slotted at *E* to allow it be moved back out of the way when placing the work in position or removing it. The clamping is accomplished by means of the cam *G* which is pivoted to the end of the clamp. The cam bears on the wear plate *F* and is operated by the thumbscrew *H*. This type of clamp is open to several objections, among which are the cost of manufacture and its limited range. If the castings should vary considerably in thickness at the clamping point the clamp

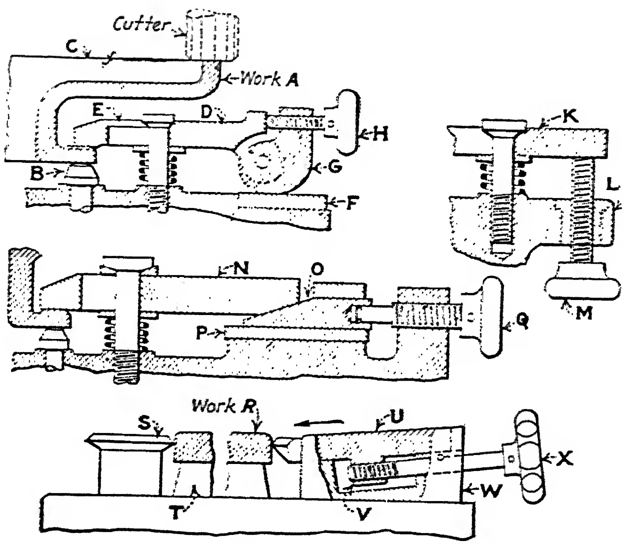


Fig. 146. Special Forms of Milling-Clamps

might not hold the work at all as the adjustment is somewhat limited.

Another type of clamp is shown at *K* for the same piece of work. In this case a projecting lug is provided on the fixture at *L* so that the thumbscrew *M* can be used to operate the clamp from beneath. This form can be frequently used on fixtures, providing the extra depth of fixture needed is not objectionable. Ample clearance for the operator's knuckles should be provided when designing this form of clamp.

Another form of sliding clamp is shown at *N*, for holding the same piece of work. This type is operated by means of the sliding wedge *O* which is forced under the end of the clamp by

the action of the thumbscrew *Q*. The wedge may be given a bearing on a hardened plate *P* if desired. Of the three clamps shown for this piece of work the one illustrated at *K* is the simplest and most practical.

An excellent method of clamping small work of certain kinds is shown at *R*. The work rests on a support *T* and is clamped against the knife-edge locater *S* by means of the sliding clamp *U*. It will be seen that the latter is set at a slight angle so that the pressure is partly downward. This form of clamp may be made up in units of several sizes and standardized. The block *W* carries the slide which is adjusted by the thumbscrew *X* acting in the nut *V*. This clamp can be utilized for many varieties of small work when clamping space is restricted.

Lever Operated Clamps.—In order to make a clamp self-contained it is often desirable to operate it by means of a lever and thus avoid the use of a wrench. If there is plenty of room on the fixture so that the handle can be revolved completely without interfering with the cutter or any part of the fixture, a lever can frequently be used to good advantage. Levers can be used on nearly all types of clamps which are operated by means of a nut, provided there is room enough so that they can be operated without interference.

Fig. 147 shows a piece of work *A* which is being milled by the cutter *B*. It is clamped in place by the slotted clamp *C* operated by lever *D*. It can be seen that if the thickness of the work should vary, the clamping lever might take the position indicated by the dotted lines at *E*, thus interfering with the cutter. If the work is finished on both locating and clamping surfaces, the variation would be very slight and the lever could be fitted so that it would not interfere with the cutter.

A special form of lever which pulls the clamp away from the work when it is loosened is shown at *N*. The work *F* locates on points *G* set in the fixture base. It is clamped down by the two points *K* in the equalizing clamp *H*, which is controlled by the lever. A cam path is cut on the lower side of the hub as indicated at *P*, the pin *O* in the clamp being controlled by the cam in such a way that when the lever is operated in loosening the clamp, a continuation of the movement causes the pin *O* to strike the end of the cam path at *Q* thus pulling the clamp back from the work. The pin *L* acts as a guide for the clamp.

In using this form, suitable allowances must be made for variations in the work in order that the clamp may work properly under all conditions. It is well to make the thread *M* of coarse pitch or even a multiple thread if the occasion warrant it. This type of clamp will be found more satisfactory on finished work where the variations are very small.

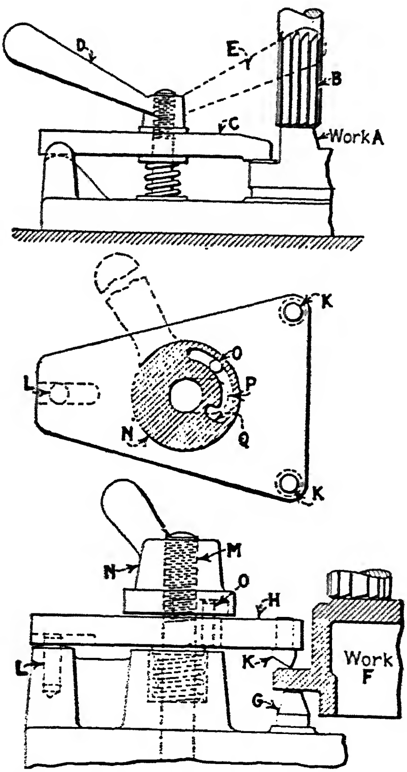


Fig. 147. Clamps Operated by Levers

Locating and Clamping Odd Shaped Work.—Work which is to be milled almost in line with a normal clamping surface is difficult to locate and clamp firmly, at the same time keeping the clamps below the end of the cutter so that there will be no interferences. A case in point is shown in Fig. 148, in which the work *A* is to be milled on the two bosses indicated. The surface *B* has been machined and is to be used for location. By

setting it on this surface, on a hardened locating plate in the fixture *C*, it can be brought up against the knife-edge locater *D* by means of the swinging clamps on the opposite side at *F*.

The locater *D* is well backed-up by the lug on the casting at *E*. The operation of the swinging clamp *F* is controlled by the thumbscrew *H* so that the knife-edge point *G* forces the piece over against the locater *D* and at the same time holds it down on the locating plate *B*. The pivot *K* on which the swinging

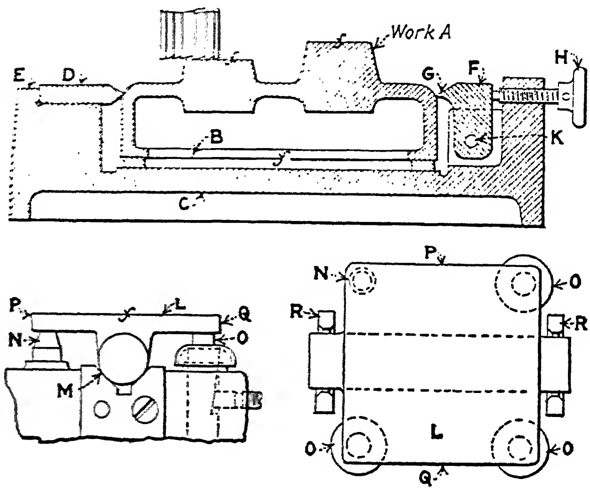


Fig. 148. Locating and Clamping Odd-Shaped Work

clamp moves should always be set well back of the knife-edge *G*, so that the action in clamping will be downward.

Another piece of work requiring a method somewhat out of the ordinary for locating and clamping, is shown at *Q*. Here the surface *L* is to be machined and the work must be located not only in relation to the under-side of the surface mentioned but also in such a way that it will bear a certain relation to the hub *M*. The method used is to locate each end of the hub in a knife-edge V-block such as that shown at *R*. This gives a location on two of the three points necessary. It can then be tipped until it strikes the fixed locating point shown at *N*, after which the three spring-jacks indicated at *O* can be released until they strike the under-side of the flange, after which they should be locked. This work could be clamped with an arrangement

similar to that previously described, using knife-edges at *P* and *Q*. Conditions similar to this are frequently found in general manufacturing and a careful analysis must always be made to make sure that the work does not locate on more than three fixed points.

Special Form of Finger Jack.—Fig. 149 shows a type of finger jack which is very useful in supporting work for profiling or milling. The principle on which this jack is based is a wedging action produced by the tapered member *A* in contact with the under-side of the plug *B*. The operator grasps the knurled screw *C* and pushes the plunger forward until the end of the jack *D* supports the work. A turn of the finger locks it in place by means of the plug shown at *E*.

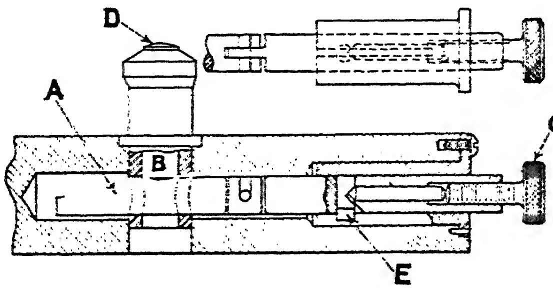


Fig. 149. Finger Jack for Milling Fixtures

Equalizing Clamps.—It is often necessary to hold two or more parts at the same time. When this condition arises, the clamps should be made in such a way that they will exert a uniform pressure on the work. An equalizing type of clamp must therefore be used.

Fig. 150 shows two pieces of work at *A* and *B* which are to be machined on the upper surface. The work locates on the blocks *C* and *D* and there is a locater on each side as shown at *F*. The base of the fixture *E* contains a spring plunger *H*, on the upper end of which is mounted a rocker *G*, so formed that the angular surfaces will come in contact with the edges of the work. The lower part of the plunger is slotted to receive a wedge *K* which may be operated in any convenient manner. The action of the wedge draws the plunger down and the rocker *G* equalizes the clamping action so that it is distributed

evenly on both parts A and B. The sectional view at L makes the construction easily understood. A clamp of this kind is useful when the work is of such a nature that it can be put into the fixture without difficulty, but if this cannot be done, this type should not be used because it requires too much movement of the plunger in order to remove and replace the work.

The two pieces of work shown at M and N are to be machined at the points O and P, therefore clamps should be provided which can be operated simultaneously, thus equalizing the pres-

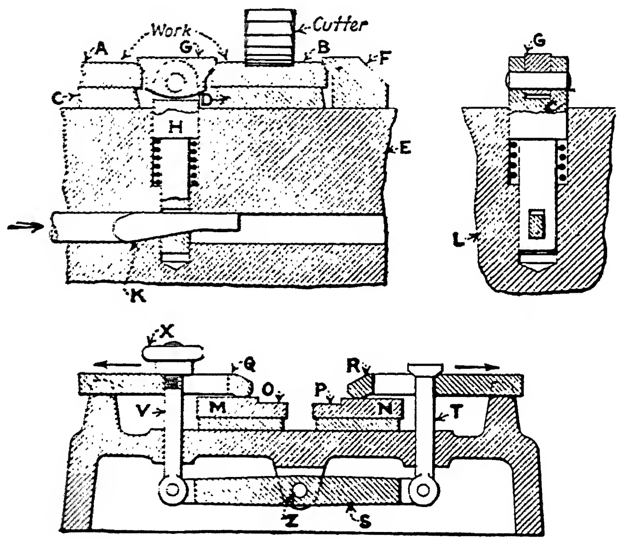


Fig. 150. Applications of Multiple Clamps

sure. The clamps Q and R are slotted so that they can be pulled back when removing and replacing the work. The clamps are operated by means of the eye-bolts T and V and their action is equalized by the lever S. When the thumb-knob X is screwed down, the same amount of pressure is applied on both clamps Q and R so that the pressure on the work M and N is the same.

This form of equalizer is very commonly used and can be applied to a variety of conditions. It is of course important that the pivot point Z be mid-way between the two operating eye-bolts T and U in order that the pressure may be uniform.

Clamping Work in Groups.—The greatest care must be used in clamping several pieces of work against each other so that

slight errors in locating will not cause inaccuracies in the finished product. A case in point is shown in Fig. 151. The work consists of four bars *A*, *B*, *C* and *D* on which a small flat surface is to be milled as indicated. The bars are located in the fixture *E* so that the bar *D* is clamped against the under cut portion *F* on one side of the fixture. It will be seen that when the thumbscrew *K* is operated, the swinging clamp *H* strikes

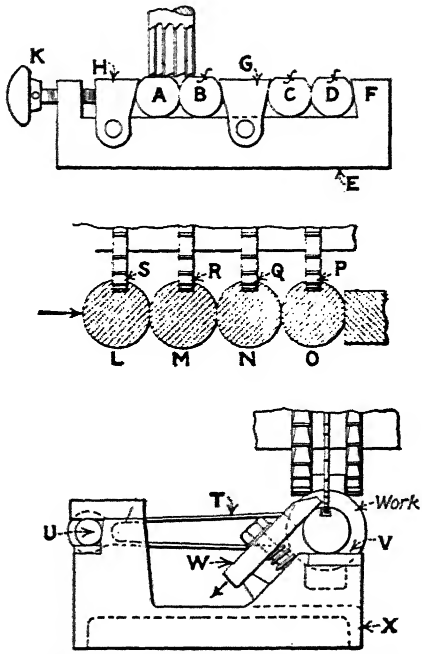


Fig. 151. Clamping Work in Groups

against the bar *A* throwing it over against *B* which in turn moves the angular rocking clamp *G* so that it forces the bar *C* against *D* thus holding the entire group of bars.

For the condition shown this method of clamping is not objectionable, but assuming that the bars were to be located for a key-way as shown at *L*, *M*, *N* and *O*, it is evident that accumulated variations would be found in the positions of all of the slots with the exception of *P*. If the bars chanced to be a trifle large the slot *Q* would be slightly off center, *R* would be a little more so and *S* still more out of alignment.

This point must always be remembered in designing fixtures for holding a number of pieces, as a condition like that shown would be very serious, in that the errors in the key-ways would make it impossible to obtain a fit on the corresponding female member.

Another method useful in clamping work in groups, is shown at *T*. This is a connecting rod in which a pin has been inserted in the small end *U* so that it may be used to locate from during the progress of the work. The work is located at the large end by means of another pin which rests on the hardened block *V* where it is securely held by the sliding clamp *W*. The fixture *X* must be so arranged that the clamp *W* can be dropped down in the direction indicated by the arrow far enough so that the work can be easily removed. The machining on the rod consists of straddle milling the two sides of the bosses and saw cutting it at the same time as indicated.

It is common practice to set up work of this kind in groups, the number of pieces to be machined at the same time being governed by the capacity of the machine and the dimensions of the connecting rod. It is evident that when one side has been cut, the work can be removed and turned over in the same fixture so that the other side can be machined.

Design of Hook-Bolt Clamps.—Some data have been given in one of the chapters on drill jigs regarding the design of hook-bolt clamps in their application to drill jigs. Similar clamps may be used for milling fixtures, although they should be much heavier than those used for drilling. Fig. 152 shows a piece of work *A* located on the plug *B*, and which must also be held firmly on the rectangular end. A special form of combined hook-bolt and jaw is used in this case. The member *D* is a bushing having a jaw cut on it at *E* against which one side of the work locates. The rod *F* has a jaw *G* at one end and passes entirely through the bushing *D*, being operated by the thumb-knob at the other end *H*. This entire mechanism will "float," and when the thumb-knob is operated, the work is firmly gripped between the jaws *E* and *G* after which the thumb-screw *K* can be tightened, locking it positively. A teat screw *L* prevents the rod *F* from turning. Attention is called to the manner in which the jaw *G* is supported at *P*.

A somewhat similar device is shown holding the work *M*. This

piece is also gripped between jaws at *N* and *O* and the hook-bolt is released by means of the spring indicated. In this particular case it is necessary to swing the hook-bolt out of position in order to remove the work, and the method used is clearly shown in the end view, the movement of the hook-bolt being indicated by the arrow and the dotted lines. The same careful

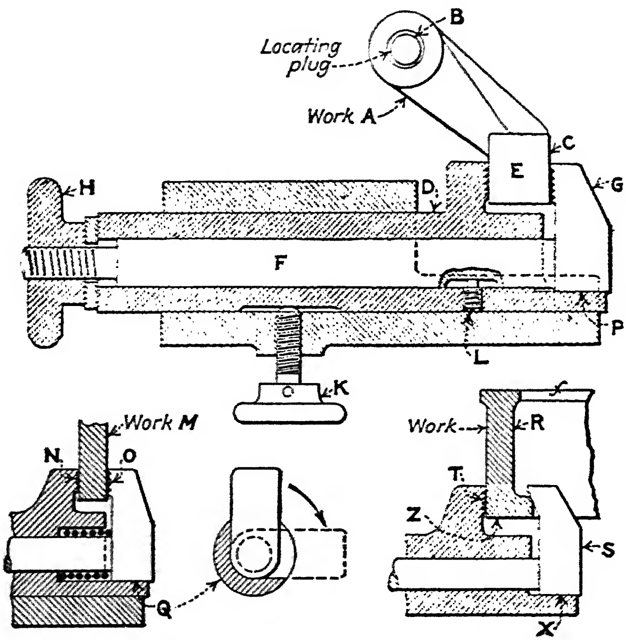


Fig. 152. Designs of Hook-Bolt Clamps

provision has been made here for supporting the heel of the hook-bolt at *Q*.

An application of a similar principle is shown in the method of holding the work *R*. The jaw *T* grips the work on one side while the hook-bolt *S* draws it down and also clamps it. Suitable locating points must be provided on which the casting may be supported. This may be done at the point *Z* by the insertion of a stud or by some other convenient method. Attention is once more called to the support of the heel of the hook-bolt at *X*.

Special Application of Hook-Bolt Clamps.—For thin work that is likely to be distorted either in the cutting or the holding,

the hook-bolt may frequently be utilized to good advantage. An application of this kind to a very difficult piece of work is shown at *A* in Fig. 153. The work locates on a central stud *B* and on hardened ring at *C*. The arms of the bracket are straddle milled at *D* and *E* and are also finished at *F* and *G*. The material is manganese bronze and the two arms of the bracket *D* and *E* are very frail. Therefore, the method of holding during the process of machining must take into considera-

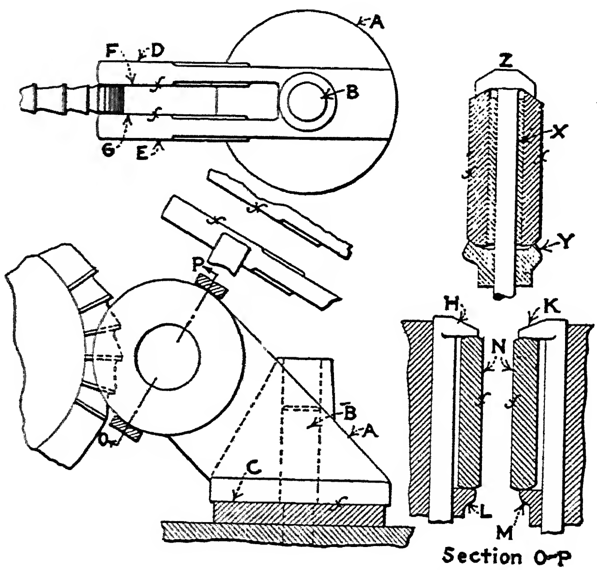


Fig. 153. Special Applications of Hook-Bolt Clamps

tion the spring of the material and clamps of special form must be used. The work must be held close to the points where the cutting is to be applied and the clamping device must be of a "floating" nature in order that the location of the work on the stud *B* and the surface *C* may not be disturbed.

A pair of hook-bolts using a principle similar to that applied to the work *A* in Fig. 152 were used for the first operation while holding the work for the milling of the inside surfaces *F* and *G*. The section taken along the line *OP* shows the two sides of the work *N* gripped at the top by the hook-bolts *H* and *K* and at the bottom by the jaws *L* and *M*. The floating action of the

hook-bolts allows the work to be securely gripped in such a way that the cutter can machine the piece without distortion.

For the second operation, which consisted of milling the outside surfaces *E* and *D*, a similar arrangement was used. The work locates on a central plug *X* through which the hook-bolt *Z* passes. The lower part of the work is held by a floating collar *Y*. Both the end of the hook-bolt and the collar are cut

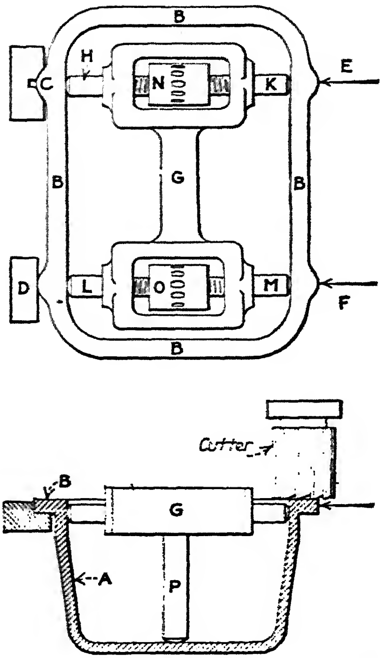


Fig. 154. Method of Supporting and Clamping a Thin Casting

away on a slight angle so that the clamping action draws the work tightly against the central locating plug *X* and gives great rigidity during the straddle-milling operation. It may be well to state that both of these fixtures were made for work requiring great accuracy and that they were operated by girls.

Holding a Large Piece of Thin Work.—In milling thin work it is important that it be held in such a way that vibrations will not be set up during the cutting operation. An efficient method of holding a piece of this kind rigidly, yet without distortion, is shown in Fig. 154. The work *A* is a deep, thin bronze cast-

ing which is to be milled along the upper part of the flange *B*. The work is located on suitable supports under the flange, in the V-block at *C* and against the locating block *D*. It is clamped as indicated by the arrows at *E* and *F*. The clamping action will obviously tend to distort the sides of the casting and as there are no lugs on the work to which clamps can be applied, the results would be very unsatisfactory. The writers have seen a fixture of this kind in which it was impossible to machine the work without distortion; in fact it was difficult to machine it at all on account of the "chatter" induced by the vibrations of the thin metal walls.

A remedy which was suggested and applied successfully is indicated at *G*. This is a "spider" of aluminum having two supporting studs *P* which rest on the bottom of the casting. At *H*, *K*, *L* and *M*, screw jacks are located, directly opposite the outside locating and clamping points.

When setting the work in this fixture the outside clamps are first set up very lightly and locked in position. The spider *G* is then set inside the work and the screw jacks set up tightly by means of the nuts at *N* and *O*. As the jacks are directly opposite to the outside holding and locating points a metal-to-metal contact is obtained which does not distort the work, yet holds it firmly so that all vibrations are "killed" and the piece can be milled with speed and precision.

The principles illustrated in this example can be applied in many similar cases. It is well, however, to note that a much better way of finishing a casting of this sort would be by using a surface grinding machine instead of a milling machine.

Equalizing Hook-Bolts.—An excellent fixture, which was designed for holding the work *A* while milling the circular form *D*, is shown in Fig. 155. The work has been previously finished in the hole *B* and also on the sides *E*. It is evident that the action of a large form cutter such as that used in milling the contour *D* necessitates exceptionally rigid support for the work in order to eliminate "chatter" during the operation. The work is located on a stud at *B* so that it rests against a solid surface at *E* and is located in the other direction by the pin *C*. It is clamped back against the shoulder *E* by means of the hook bolts *F* and *G*, these being operated by the equalizing bar *H*

through the action of the hand wheel *M* and the screw *K*. The latter works against a hardened block at *L*.

The hook belts are provided with camslots at *O* and *P* which are so located that when the pressure of the spring at *Q* and *R* is exerted after the handwheel is loosened, the hook bolts turn 90 deg. and are thus out of the way so that the work can be readily removed. In other words, when the hook bolts are

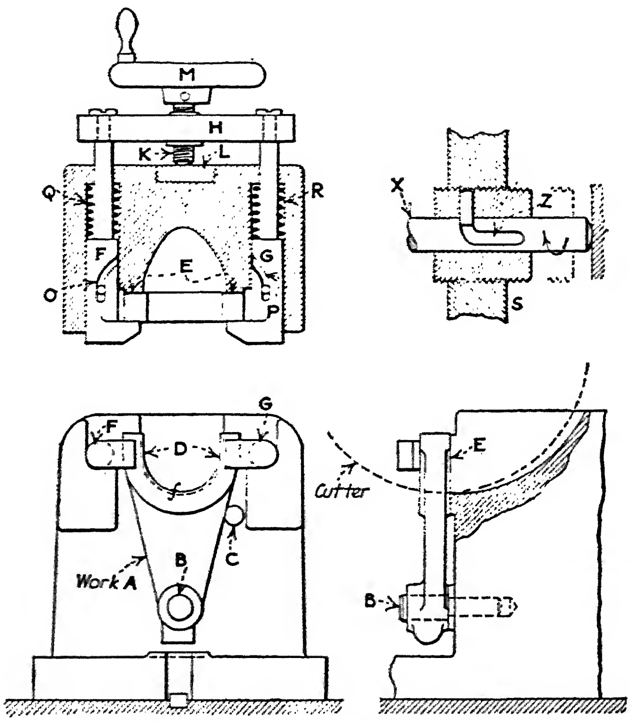


Fig. 155. Fixture with Equalizing Hook Bolts

pushed out away from the work by means of the springs, a pin in the campath makes them revolve in the manner noted. An additional refinement can be used as shown at *F*, if conditions warrant it, by mounting the handwheel on the shaft *X* in which a bayonet lock *Z* is cut. A method like this would make the operation of the mechanism somewhat faster than the example previously described. The advantages of this type of fixture are the extreme rigidity that is obtained and the fact that the

operator is not obliged to put his hands near the cutter. It is rapid in operation and the construction is such that the upkeep is very economical. The use of air-operated chucks and other clamping devices is becoming more and more general for work requiring careful holding or rapid operation. The majority of present day factories are equipped with air compressors and

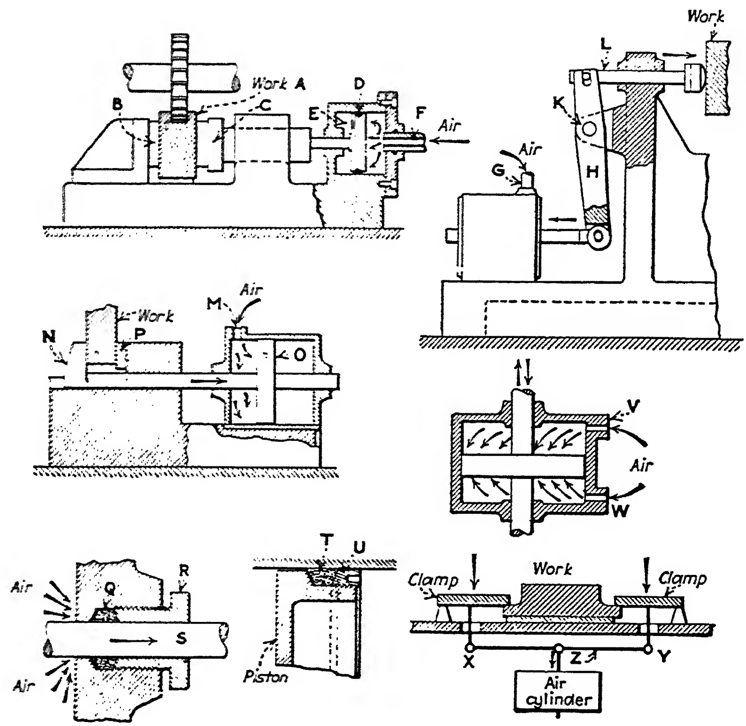


Fig. 156. Principles of Pneumatic Clamping

pipe lines extending to the various departments of the shop. With such equipment, advantage should be taken of the opportunities for using air pressure to operate fixtures of various kinds.

Principles of Pneumatic Clamping.—Fig. 156 shows a few diagrams which will assist the designer in understanding the principles of pneumatic clamping. The work shown at *A* is being held for the milling operation indicated between the jaws *B*

and C of a pneumatic holding fixture. The air cylinder E is a part of the fixture itself. The air enters the chamber at the port F and acts upon the head of the piston D, which is coupled to the sliding jaw C. The operation of the mechanism is very simple as it only requires the turning of a lever to admit or release the air. The amount of power developed is determined by the pressure carried in the pipe line F and the diameter of the piston D. Increased power can be readily obtained by the use of compound levers, bell cranks or similar appliances.

In another example the air enters the cylinder through a pipe at G and acts against a piston connected to the lever H. This lever operates a sliding rod at L, applying pressure in the direction indicated by the arrow. The amount of leverage obtained is dependent on the position of the fulcrum pin K.

Another diagram shows the piston connected to a hook-bolt N in order to clamp the work against the locating surface P. The air enters the cylinder at M, acting against the piston O.

A point of great importance in connection with the use of air pressure for operating various devices, is the matter of packing to prevent the escape of the air and consequent loss of holding power. Lubricated asbestos packing is frequently used in connection with suitable glands as shown at Q and R, the packing being drawn tightly around the shaft S. A method of packing a piston is shown at T, the packing being compressed by means of an annular ring-nut U. It is evident that air must frequently be applied in both directions in order that the piston may operate effectively. The diagram shows two ports at V and W which can be closed and opened alternately as required, by means of a valve.

Pneumatic clamping can be applied through equalizing devices of various kinds; one of which is shown in diagrammatic form. Here the air acts on the equalizing lever Z through the air cylinder in such a way that the pressure acts uniformly at the points X and Y, thus operating the clamps. To the designer of high production tools the possibilities of air clamping should be given the most careful consideration, and in particular cases where it is desirable to operate a number of clamps simultaneously with a uniform pressure it may often be possible to adapt pneumatic methods to advantage.

CHAPTER VII

DESIGN OF MILLING FIXTURES

FIXTURES FOR HAND-MILLING—FORM-MILLING ATTACHMENTS—DESIGN AND OPERATION OF INDEXING FIXTURES—SEMI-AUTOMATIC AND AUTOMATIC INDEXING DEVICES—USES OF TWIN FIXTURES—FIXTURES FOR CONTINUOUS MILLING.

Hand-milling fixtures can be used profitably on small light work requiring high production, providing the cuts to be made

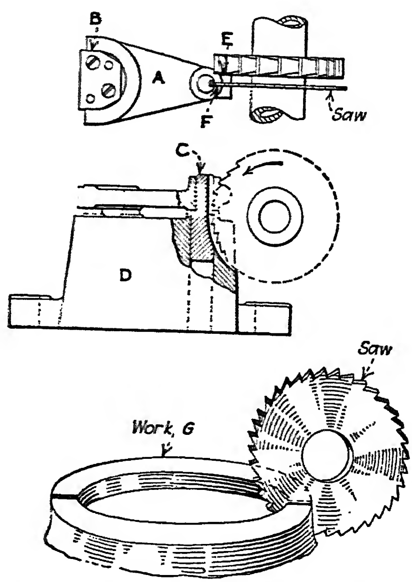


Fig. 157. Type of Hand-Milling Fixture

are short so that the operator is not required to feed the work by hand any great distance. A good example showing the principles of a hand-milling fixture is shown in Fig. 157. The work *A* is located on the half-bearing *B* at one end of the fixture and

is supported at the other end on a stud C in the body of the fixture as indicated at D. No clamps are shown for this piece of work as it is the intention to illustrate here only the principle of down cutting. The work to be done is the facing of the boss at E and the cutting of the punch binder slot at F. Both of these operations are done at the same time.

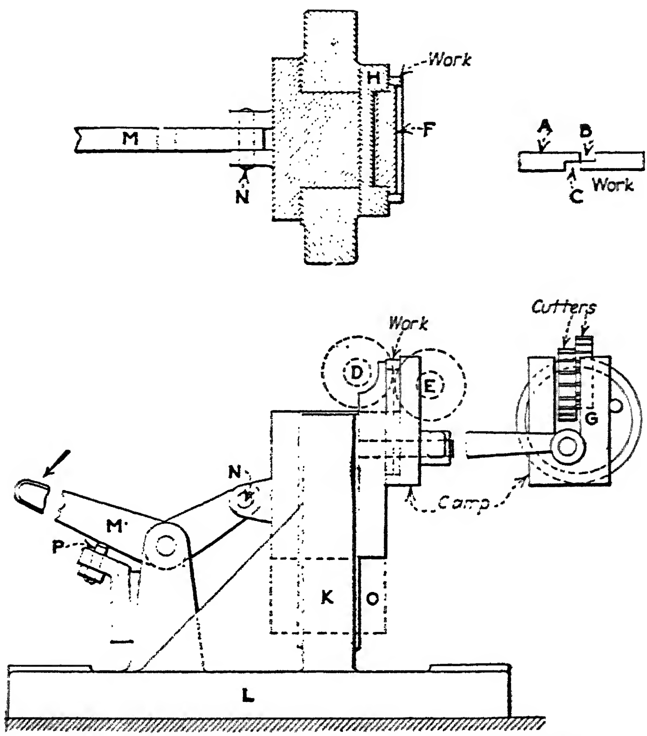


Fig. 158. Fixture for Milling a Lap-Joint Piston or Packing Ring

When a hand-milling machine having a vertical feed is used, a weight may be hung on the end of the handle so as to make the feeding action automatic. If it is desired to use a fixture of this kind on the other type of hand-milling machine, the work can be fed against the cutter horizontally. An example of a piece of work suitable for a hand-milling fixture is shown at G. The work is a ring which is to be cut in two by a narrow saw cut as indicated. Rings of this kind can be cut either singly

or in multiple, depending upon their thickness and the method of holding.

Cutting a Lap-Joint Packing Ring.—The work shown at *A* in Fig. 158 is a lap-joint packing ring which has been turned to a sufficient diameter to allow for the cutting out of the portion *B* and *C*. In order to do this work as rapidly and economically as possible a fixture was designed to be used on a light plain-milling machine in connection with a special head carrying two cutters mounted as shown at *D* and *E*. One of

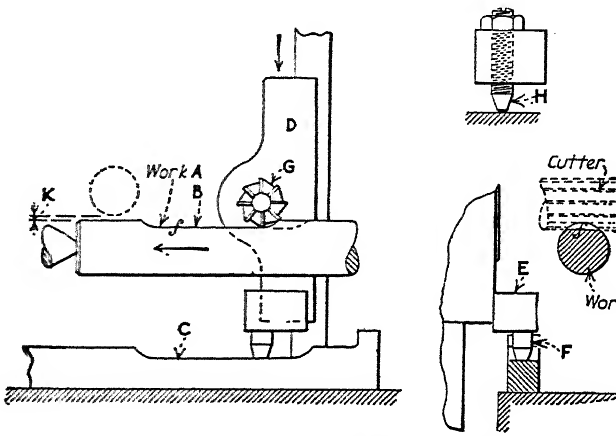


Fig. 159. Automatic Form-Milling Attachment

these cutters is mounted slightly below the other so that the cutter teeth will not interfere with each other in their action. The work is mounted on a locating plug shown at *F* and is clamped in place by means of a screw lever on the U-washer *G*. This washer is so located that it will always bear the same relation to the cutters in order to avoid interference with them. The stud *F* is mounted in a slide *H* which is fitted to the vertical member *K* on the fixture base *L*. A bell-crank lever *M* is attached to the slide by means of a pin *N* in a lug at the back of the slide. Suitable gibs should be provided on the slide to take up wear. In operating the device, the work is placed in the fixture when it is in the position shown by the dotted lines at *O*, then it is fed up past the cutters until the lever *M* strikes the stop pin *P*. The pin may be adjusted to permit the proper movement.

This fixture requires in connection with it a special design of milling head to carry the two cutters *D* and *E*, but as an arrangement of this kind can be easily made there is no objection to its use when the occasion warrants it. It is well to note at this point that when it is necessary to design sliding fixtures which are in continual use, provision should always be made for adjustment of the slide by means of suitable gibs.

Form-Milling by Means of a Special Attachment.—A special form can be easily cut on a hand-milling machine by the use of a forming attachment such as that shown in Fig. 159.

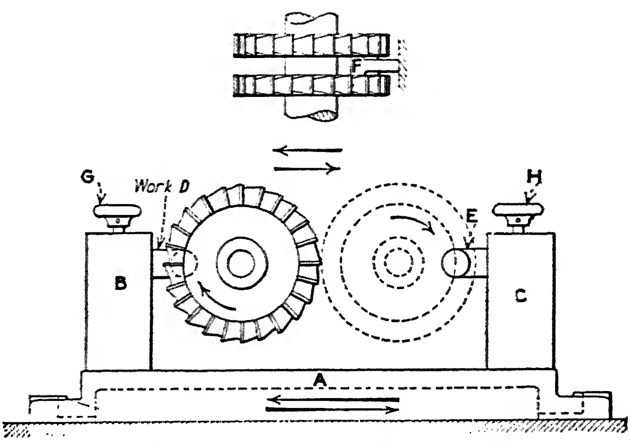


Fig. 160. Reciprocating Milling Fixture

The work *A* is a shaft having a flat milled on it as indicated at *B*. In order to do this work easily and automatically, a form-plate *C* can be applied to the table of the milling machine in such a way that it will control the movement of the slide *D* by means of the block *E* in which is mounted a forming pin *F*. This pin rides along the form shown at *C* and the cutter *G* being mounted in the head *D* naturally follows the outline required. If the head *D* is fed downward by means of a weight, it is only necessary for the operator to place the work in position and operate the feed handle for the table. It is advisable to make the forming pin with an adjustment as shown at *H* in order to take care of variations in the cutter diameter.

The forming plate *G* is so made that it will lift the cutter above the surface of work as indicated at *K* at the completion

of the cut. Attachments of this kind can be made cheaply and will handle many kinds of work where a form cut is required.

Reciprocating Fixtures.—It is often found an advantage to make-up duplicate fixtures which can be so arranged on the milling-machine table that the operator can load one fixture while the cutter is operating on the other. In this manner a great deal of time is saved and the operation is almost continuous. Fixtures of this kind can be applied to a great many

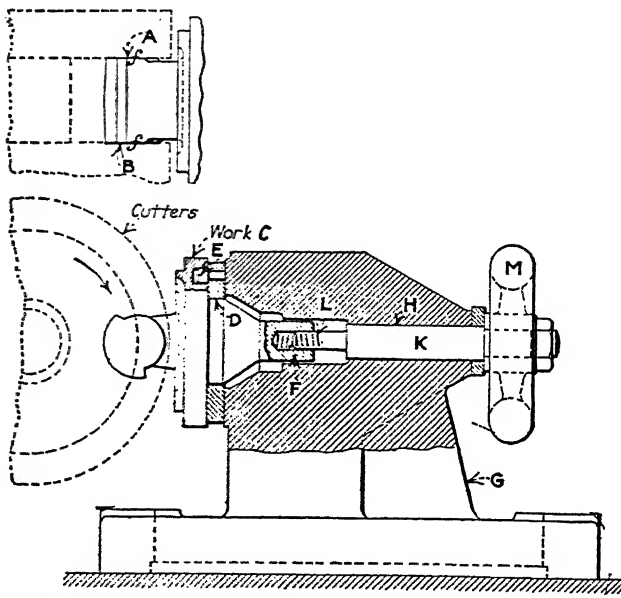


Fig. 161. High Production Straddle-Milling Fixture

kinds of work and are particularly useful for straddle or slot milling.

A very good example is shown diagrammatically in Fig. 160. Two holding fixtures *B* and *C* are set at opposite ends of the fixture base *A*. The work *D* is shown in process of machining while the piece at *E* is being removed. The cutting action on this piece is shown by the diagram at *F*. The work is held by means of thumbscrews *G* and *H* which operate binding shoes. This particular example is only intended to show the principles involved in the design of reciprocating fixtures, not details of

construction. Care must be taken that fixtures of this kind are placed far enough apart so that the operator is not endangered when replacing or removing work.

High Production Straddle-Milling Fixture.—Another type of fixture which can be used either singly or in a reciprocating manner is shown in Fig. 161. The operation is the straddle-

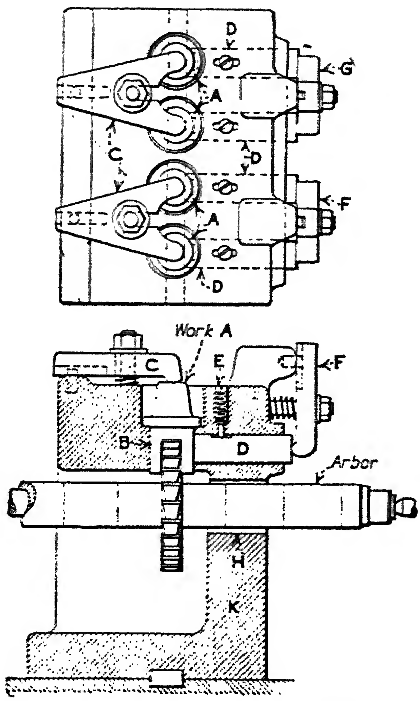


Fig. 162. Multiple Milling Fixture

milling of the surfaces *A* and *B* on the work *C*, which has been partly finished in a previous operation. It is located in the hardened ring *D* and its radial position is determined by means of the pin *E*. The end of the work is threaded at *F* and this fact is utilized in order to obtain a positive method of holding it in position.

The fixture base *G* has a long bearing at *H* in which the rod *K* is a running fit. The end of the rod is threaded at *L* to fit the end of the work and the handwheel *M* is used to draw the

work back firmly into its seat. This fixture is very rigid, is rapid in operation and has given excellent service.

Under-Cut Multiple Milling Fixture.—Chips often accumulate in the locating seats, making it difficult to hold work and causing other trouble. The fixture shown in Fig. 162 was designed to obviate this chip trouble and the idea may be valuable for adaptation to other conditions. The fixture shown is used for milling the slot in the work *A* from beneath. It may be argued that the cutting action in this case is partly against the clamps, but in reality there is very little pressure exerted directly against the clamps as the thrust of the cut is partly

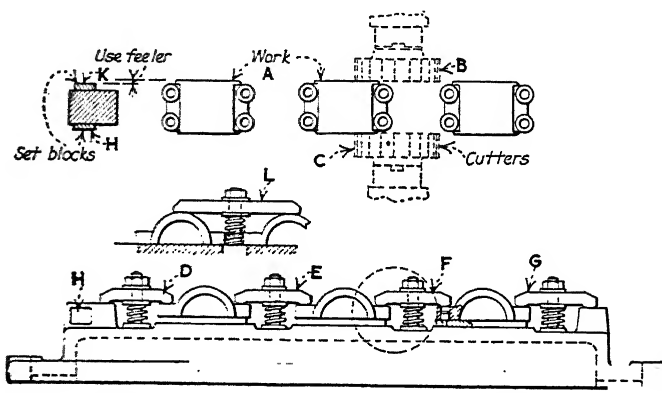


Fig. 163. Types of Fixtures for Duplex Milling

against the surface of the holes in which the work locates. The pieces rest in cylindrical pockets *B* in the body of the fixture and are clamped down by means of the double clamps *C*. Four pieces are held in the same fixture, each clamp being so designed that it will hold two pieces at once. In addition to the hold-down clamps, binder shoes are provided for each piece as shown at *D*. These binders are formed at the end to the shape of the work and are prevented from turning by means of the teat-screws *E*. Two of the binders are operated at the same time by means of the equalizing clamps at *F* and *G*, these acting on the ends of the binders.

Attention is called to the way in which the cutter arbor passes through a cored slot in the body of the fixture at *H*. By passing the arbor through the fixture *K* an out-board support is

obtained by means of the over-arm on the milling machine, thus making it possible to produce work much more rapidly than could be done with an overhanging cutter. A careful study of this fixture will be of advantage as the principles involved may be found useful in numerous cases where multiple-fixtures are needed.

Multiple Fixture for Duplex Milling.—The duplex-milling machine is occasionally used for facing off both sides of work which might also be straddle-milled with large cutters. An example of this kind is given in Fig. 163 and we are citing this case to show the disadvantages and lost time occasioned by a poorly arranged milling fixture. The work *A* consists of bearing caps which are to be machined on each side by the cutters *B* and *C* as indicated. The work is located on a finished surface and on pins in two holes in each cap. Clamps are provided at *D, E, F* and *G* to hold the work down while milling. Set blocks are also located on the fixture at *H* and *K*, which are used with a feeler to set the cutter. Attention is called to the spacing of the work on this fixture, as the pieces are set so far apart that the cutter is "cutting air" about half the time. In order to save time and increase production, the pieces should be set as closely together as possible. There is no reason why an arrangement such as that shown at *L* cannot be used, as the only space necessary in this case is clearance for the bolt and the spring. If arranged in this way more work could be placed on a fixture of the same length and each clamp would hold two pieces so that the clamping action would be more simplified and much more rapid.

Spline Milling.—The diagrams shown in Fig. 164 are intended to give the student a better idea of the uses and principles involved in the milling of splines. In designing spline-milling fixtures the first thing for the designer to remember is that the height of the spindle above the table is absolutely fixed and there is no adjustment vertically. Hence the fixture must always be designed to certain dimensions which vary among the different manufacturers.

Several standard fixtures can be purchased as equipment for the machine, these being useful for the holding of plain bars and for flat work. A bushing holder with taper collets to hold standard taper shanks can also be obtained. These fixtures can

be adapted for a variety of uses when only a few parts are to be machined, but when a number of pieces of the same kind are to be manufactured, it is usually necessary to design special fixtures in order to obtain uniformity in the product.

Action of Cutters.—Several diagrams are given in order to show the cutter action when the machine is in operation. The diagram at *A* shows the cutters *B* and *C* approaching the work and ready to cut. Diagram *D* shows both cutters *B* and *C* part

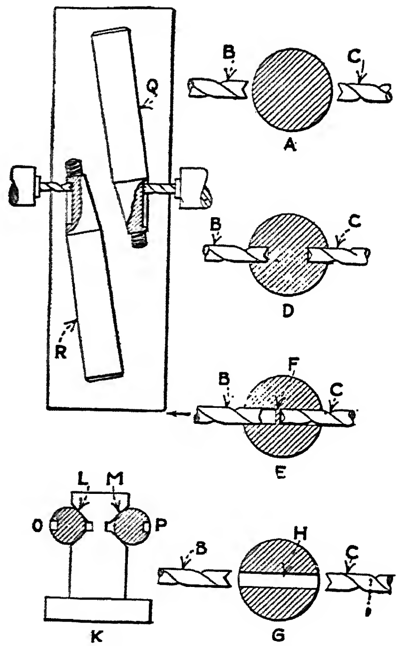


Fig. 164. Explanatory Diagram of Spline and Slot-Milling

way through the work. Diagram *E* shows cutter *B*, which has approached almost to the center line of the work, withdrawing in the direction of the arrow while the cutter *C* continues and takes out the remaining metal at *F*. The diagram at *G* shows the completed slot at *H*.

As it is absolutely necessary that key-ways be located central with the shaft, any method used for location must take this point into consideration. In the example shown at *K* it will be noted that the V-blocks *L* and *M* are arranged so that the center line *OP* is directly in line with the spindles.

When tapered shafts like those shown at Q and R in the upper part of the illustration are to be spline-cut they may be set as indicated in order to utilize both spindles of the machine. Shafts having single splines should always be cut in pairs, in order that the machine may be worked at maximum efficiency. Generally speaking, spline-milling fixtures are simple in design and it is, therefore, unnecessary to illustrate many types. The principles given are sufficiently clear to enable a designer to make fixtures of this kind without difficulty.

Spline-Milling Fixture for Connecting Link.—One example of a spline-milling fixture is shown in Fig. 165. The work A

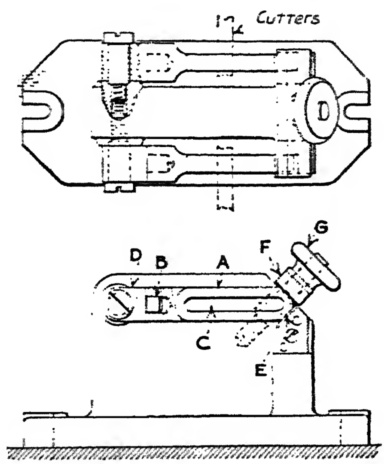


Fig. 165. Example of Spline-Milling Fixture

has been previously milled on the sides and the hole B has been reamed as indicated. The slot C is to be machined on the spline-milling machine. Two pieces are held at the same time as shown in the upper part of the illustration, each being located on a swiveling stud D by means of a pin which enters the hole B. The other ends locate on the angular blocks E, being clamped in place by means of the equalizing clamp F operated by the thumb-knob G. This fixture is very clean in its general appearance and is of simple, though efficient, construction.

Indexing Fixtures.—Manufacturing conditions frequently make it necessary to design indexing or continuous milling fixtures in order to obtain maximum production. There are many

factors which influence the design of such fixtures, consequently the tool designer must be continually on the watch for parts which can be handled to advantage in this manner. In analyzing the operations on a given piece of work to determine the kinds of fixtures to be used, the following points should be considered: (1) Production required; does it justify the use of multiple holding fixtures for continuous milling? (2) Shape and general outline of work. If work is of such shape that pieces cannot be set up close enough together to permit continuous cutter action, it will not pay to make up fixtures for continuous

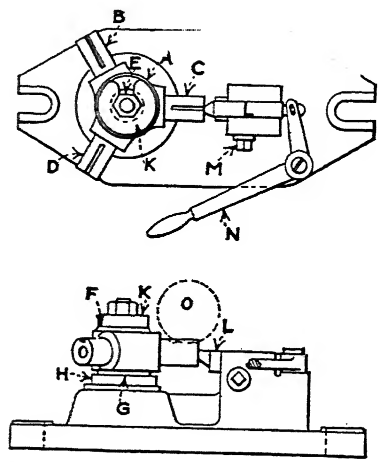


Fig. 166. Simple Indexing Milling Fixture

milling. A piece of work which is to be milled at both ends and which cannot be conveniently re-set, may sometimes be placed in an indexing fixture in such a way that one end may be milled and the fixture indexed to allow the other end to be machined without disturbing the setting of the work. Several examples of fixtures of this kind are given in this article. An indexing fixture may often be required when pieces are to be cut into two or more parts; for example, a ring casting which is to be cut up so that it will make three parts. (3) Surfaces to be machined. This item determines to a large extent the type of machine selected for the work, and the arrangement of the surfaces also influences the design of the fixture. (4) Cost of the fixture. This matter is an important one and should be

determined by the production required, rapidity of operation and convenience of handling.

There are so many points to be considered in connection with the design of indexing and continuous-machining fixtures that it is difficult to specify them in general notes, but they will be mentioned specifically in connection with the various designs of fixtures illustrated and described in this chapter.

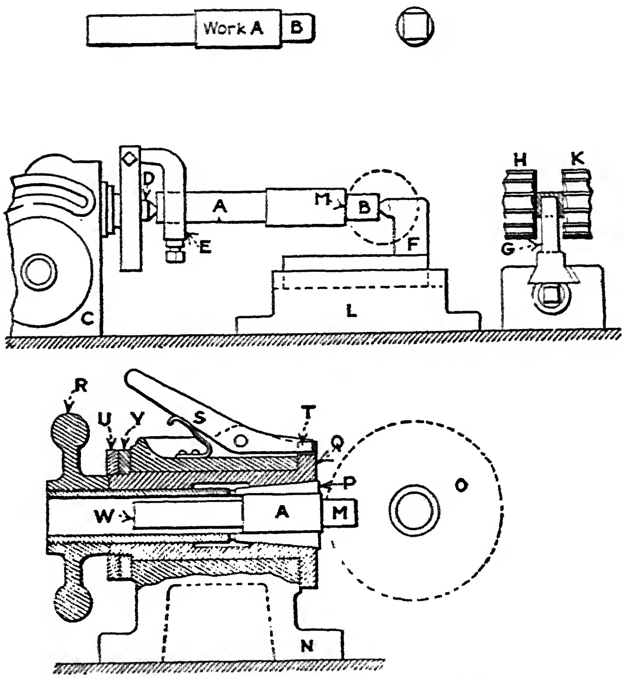


Fig. 167. Fixtures for Milling a Square Shaft

Simple Index Milling Fixtures.—In taking up index milling fixtures, the simpler forms are given first, gradually working up to those more complicated. Fig. 166 shows a "spider" *A* having three arms *B*, *C* and *D* which are to be grooved as indicated. The hole *E* and the faces *F* and *G* have been machined and the three arms have been centered and turned.

The work is located on the hardened stud *E*. The sliding point *L* is brought up so that it enters the centered end of the arm *C*, then the binder *M* and the nut on the C-washer *K* are

tightened. The sliding point *L* is operated by the lever *N*. Attention is called to the way in which the sliding point is cut away on its upper surface to give clearance for the cutter *O*.

It is necessary that the C-washer and the binder *M* be loosened when indexing from one position to the other, but as this can be done rapidly and as the groove dimensions do not have to be particularly accurate, the results obtained are satisfactory.

Fixtures for Milling a Square Shaft.—There are many cases in general manufacturing where a shaft is to be squared up at one end like the example *A* in Fig. 167. The portion *B* must be milled on four sides so that it will be perfectly square. This can be done in several ways, two of which are shown in the illustration. The index head *C* is used to obtain the correct relation of the sides of the shaft to each other while milling; the work being held on the center *D* and driven by means of the dog *E*. The other end of the work *B*, which is to be squared, is held on a special sliding center *F* which is made narrow as indicated at *G* in order that the cutters *H* and *K* may pass it without interference. The sliding point and the block *L* must be made to suit the local conditions. After two sides have been milled, the cutters are withdrawn while the work is indexed 90 deg. by means of the head *C*, after which the second cut is taken to complete the piece. If it is necessary that the shoulder at *M* be perfectly square the table must be fed in the direction indicated by the arrows.

Another example of an indexing milling fixture for the same piece of work is shown at *N*. This is a self-contained fixture which can be used with straddle mills as indicated at *O*, or with a single end milling cutter, or with two cutters arranged like those at *H* and *K*. The work is located in a spring collet *P* which is drawn back into the index sleeve *Q* by means of the handwheel *R*. The indexing is accomplished by means of the lever *S* which engages suitable slots in the edge of the index plate as shown at *T*. Attention is called to the method of adjusting the indexing member by means of threaded collars at *U* and *V*. This fixture will hold the work firmly. A permanent stop should be provided against the end of the shaft *W*, so that end location will not be affected by slight variations in the diameter of the work which might allow the collet *P* to be drawn

into the chuck more or less thus causing variations in the position of the shoulders *M*.

This piece of work can also be handled in a fixture so designed that the work is held vertically to allow the cutters to pass completely by the portion to be squared up.

It is often possible to set up two or more pieces in an index milling fixture, thus increasing the production without extending the setting-up time any appreciable amount. In Fig. 168 the work *A* consists of collars which are to be grooved in two places as shown at *B* and *C*. Four pieces at a time are set up on each of the studs *D* and *E*, these studs being located in an

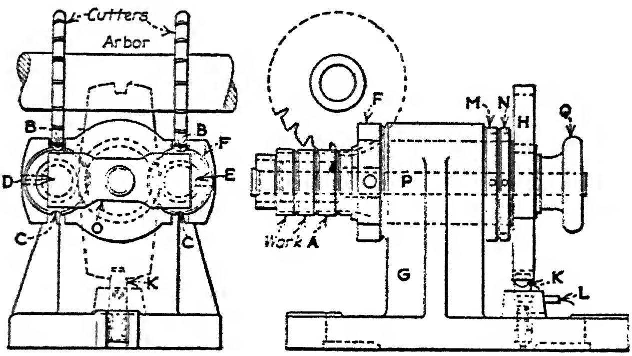


Fig. 168. Twin Indexing Milling Fixture

indexing member *F*. This member has a bearing in the fixture base *G* and it is provided with a suitable index plate *H* as shown. A very simple method of indexing is used in this fixture, the pin *K* engaging an angular slot in the edge of the plate. The index plunger is disengaged by pressure on the pin *L*. Adjustment for wear is provided by means of the two nuts *M* and *N*. The work is clamped by means of the strap *O* through the action of the rod *P* operated by the hand knob *Q*.

The cutting action on these pieces is toward the solid portion of the fixture and as the cut is not very deep vibration of cutters and fixture is eliminated.

Index Fixture for Castellating Nuts.—Ordinarily the manufacturer who uses a great number of castellated nuts buys these from some firm specializing in their manufacture. Occasionally, however, some special size is required which cannot be obtained

from the manufacturer in the required time, so that it becomes necessary to design a special fixture for the purpose of castellating.

Fig. 169 shows a fixture of this kind in which the nuts *A, B, C* and *D* are held on one side of the fixture while the nuts *D, E, F* and *G* are loaded into the opposite side. The method

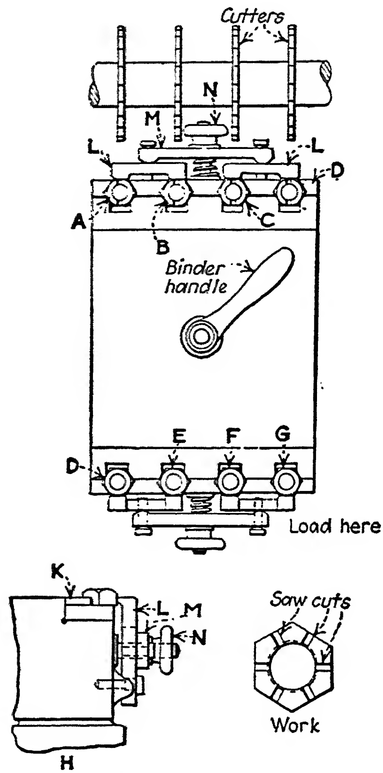


Fig. 169. Index Fixture for Castellating Nuts

of locating the work is clearly shown at *H*. The nut rests in a shallow V-block *K* and is clamped in position by means of the equalizing clamps *L* and *M*, which are operated by the same thumb-knob *N*. No indexing is provided for the three cuts on the nut as it is only necessary to loosen the knob *N* in order to release them so that they can be turned around by hand. The action of this device is not as rapid as some, yet it is capable

of giving very good results and is sufficiently accurate for commercial work. A suitable indexing device must be provided for the different positions of the fixture. The method selected can be any one of several which have previously been described. A binder handle should be provided to hold the fixture firmly after indexing.

Indexing Fixture for Cutting Bronze Rings.—One of the principal uses of indexing fixtures is for cutting and splitting into segments various pieces which have been machined in cir-

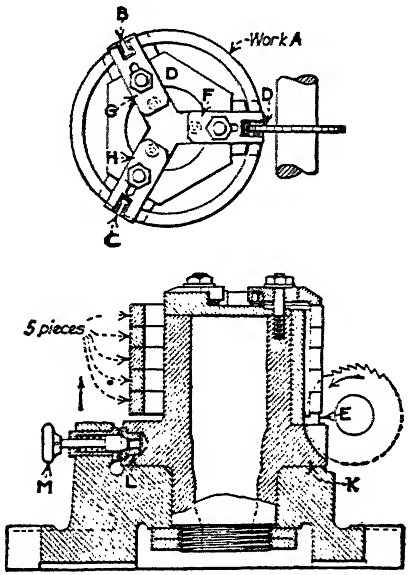


Fig. 170. Index Fixture for Cutting Bronze Rings

cular form in order to cheapen the cost of manufacture. An example of this kind is shown at *A* in Fig. 170. The work is a bronze ring about 12 in. in diameter which is turned up, bored, and faced before cutting into the three parts indicated at the points *B*, *C* and *D*. Five pieces are held at the same time on the arbor *D*, which is relieved so that the work only fits it for a short distance at the points where the cutting action is to take place. The lower ring locates on three hardened blocks *E* and all of the rings are clamped down by means of the three clamps *F*, *G* and *H*.

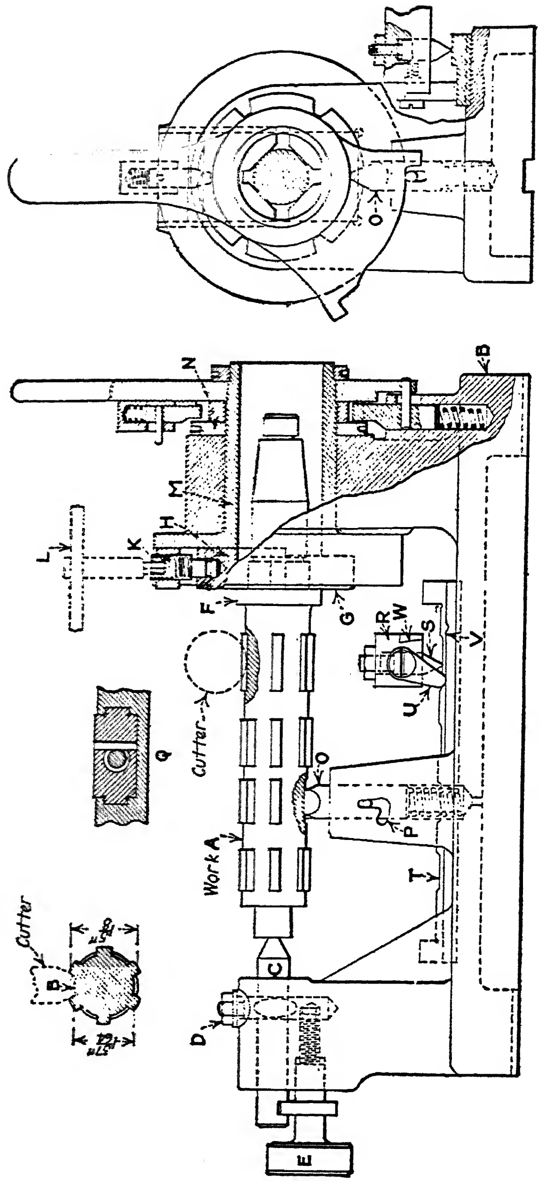


Fig. 171. Semi-Automatic Indexing Fixture

The clamps are slotted to allow the cutter to pass through them and they are located in a slotted plate so that they can be moved back when locating and removing the work. The indexing member *K* is provided with bushings at *L* to take care of the three indexing positions required. A simple type of index pin such as that shown at *M* is all that is required for correct indexing. The fixture is made quite heavy in order to absorb the vibration of the cut. This design taken as a whole will be found useful for many other operations of a similar nature, and it will be found that better results will be obtained by making it of rather heavy construction.

Under-Cut Indexing Fixture for Shaft.—A fixture which is quite out of the ordinary is shown in Fig. 171. The work *A* is a splined transmission shaft which is so designed that the portion *B* indicated in the sectional view must be undercut between the various splines. This cut is not a heavy one. as the relief required is only a few thousandths, yet it is of great importance that it should be made rapidly and economically. The machine selected for this work is a Whitney hand milling machine having a weight feed to the head of the machine. The fixture base *B* is provided with an adjustable center *C* at one end with a binder at *D*. Adjustment is by means of the special screw *E*, clamping the shoulder *F* against the face of the V-block *G* in the indexing head. An adjustable V-block is provided at *H*, the adjustment being made by means of the screw *K* and a special socket wrench indicated by the dotted lines *L*. The sectional view *Q* shows the construction of this jaw. Both V-blocks are located in the index spindle *M* which is provided with an indexing mechanism similar to one which has been previously described. Suitable adjustments are provided to take up wear as indicated at *N*. The work is located for the first cut by means of a plunger *O* which makes a contact between the splines on the shaft. This locater is not used except when the work is first placed in the fixture. While the various operations are taking place the pin is pulled down and locked by means of the bayonet lock *P*.

The sliding head of the machine is provided with a block *R* which has a follower point *S* so arranged that it will run along on the former plate *T* until the end of the work has been reached, when the swinging cam *U* strikes the recess *V*. This

happens at the end of the cut and the moment the table feed is reversed the swinging point U strikes against the shoulder W and remains there during the reversal of the table thus causing the cutter to lift slightly away from the table so as to avoid interference.

A fixture of this kind is rapid in operation and will produce excellent results. The principles employed here can be used to advantage on other fixtures for similar work.

Semi-Automatic Indexing Device.—It is possible to design a fixture for a hand milling machine so that it will index auto-

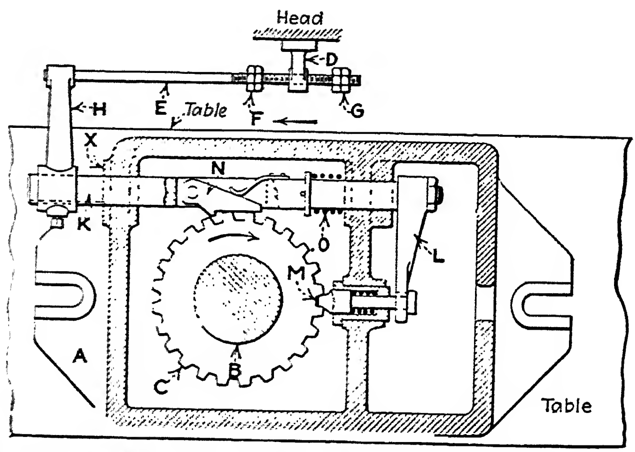


Fig. 172. Semi-Automatic Indexing Device for Hand Milling Machine

matically as the table travels backward and forward. One device of this kind is shown in Fig. 172. This mechanism consists of a fixture base A, shown in partial section, in which an indexing shaft B is mounted vertically. The upper part of this shaft passes through the fixture so that the work to be milled can be attached to it. It can easily be arranged so that it will operate a table of suitable diameter and the latter can be provided with clamps or locaters for the work.

It may be mentioned here that this mechanism is suitable only for work having a number of short radial cuts spaced from 10 to 20 deg. apart as the indexing movement obtainable is too small for indexing 45 or 90 deg. The index wheel C is mounted on the vertical index shaft B, the notches being cut in accordance with the requirements of the work that is to be machined.

On some convenient portion of the machine such as the head, a bracket *D* is fastened, and through it passes the control rod *E* which is provided with adjustable locknuts at *F* and *G*. As the nuts *G* strike the bracket when the table is moving in the direction indicated by the arrow, the arm *H* is held in a fixed position so that rod *K* pulls out the lock pin *M*, to which it is connected by the arm *L*. As the table continues to travel, the pawl *N* engages a tooth of the index wheel and indexes the mechanism to a point determined by the adjustment of the arm *H* on the shaft. After the arm strikes the shoulder at *X* the

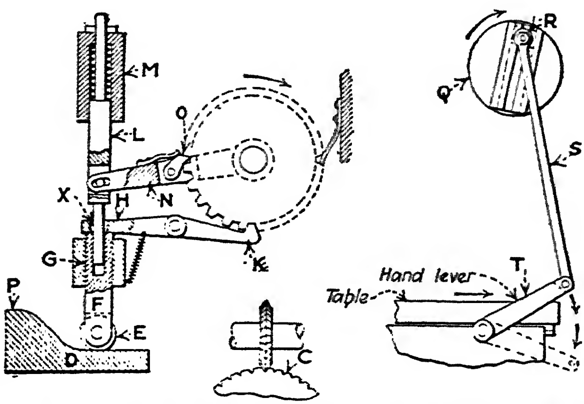


Fig. 173. Automatic Indexing Device for Hand Milling Machine

operator reverses the table feed and the spring *O* returns the operating members to their normal position as shown.

The amount of movement which can be obtained on the index wheel *C* is somewhat limited, consequently care must be taken when designing a mechanism of this sort to be sure that the action of the pawl *N* is such that it will work properly. A very good point about this device is that all the working parts are concealed in the base of the fixture so that there is no chance for chips or dirt to clog it up and interfere with its working.

Automatic Indexing Device for Hand Milling Machines.—A diagram of another mechanism having similar indexing features is shown in Fig. 173. These parts are indicated only

in order to make clear the working of the mechanism, but the entire application is not specified. Let us assume that the index stud *A* is suitably mounted in a fixture and that the upper part of this stud is connected to the table on which the work is mounted. An index wheel is provided at *B* for a number of notches to correspond with the work which is to be done. The index pawl lever *H* is so mounted that it is controlled by the sliding member *F* which has a bearing at *G*. The movement is controlled by the cam *D* which is fastened to a stationary portion of the machine. As the table travels in the direction indicated by the arrow, the roller rides up on the cam until it reaches the point *P*, the height of which determines the amount of indexing obtained.

It is evident that the lever *H* is first moved by the end of the push rod *F* until the portion *K* releases the index wheel. A continuation of the movement of the part *F* acts against the rod *L* and thus moves the lever *N* and turns the index wheel through the pawl *O*. The rod *L* is mounted so that it is a slide fit at *M* and also in the push rod *F*. Care must be taken to allow plenty of clearance in the hole *X* in order to permit the necessary movement. As the machine table returns, the springs force the push rod back against the cam until it rides once more in the position shown.

This mechanism can be operated automatically if desired by using a special countershaft above the machine and mounting on the end of this shaft a face-plate *Q* in which there is a slot as shown. The end of the rod *S* can be adjusted on the block *R* to give the proper amount of "throw" to the hand lever *T*. The speed at which the countershaft is run must be very slow. A number of devices of this kind are in use and have been found to work out very satisfactorily for work which does not require very accurate indexing.

Connecting Rod Index Fixture.—When any kind of a double-end lever or a rod like a connecting rod is to be milled at both ends it is very often difficult to hold it properly, if a re-setting is necessary after one end has been milled. In the standard type of connecting rod for automobile motors, the subsequent operations are greatly helped if all the milling can be done without disturbing or re-setting the work. An excellent example of this kind is shown in Fig. 174.

In the diagram work A is shown in position in order to illustrate the principles involved in the milling. The work is set so that the large end B and the small end C of the two connecting rods are at the same end of the fixture. The cutters D and E are spaced so that they will face both sides of the boss B, and the cutters F and G both sides of the boss C. The work is located on an indexing member K mounted on the base H and rests in V-blocks

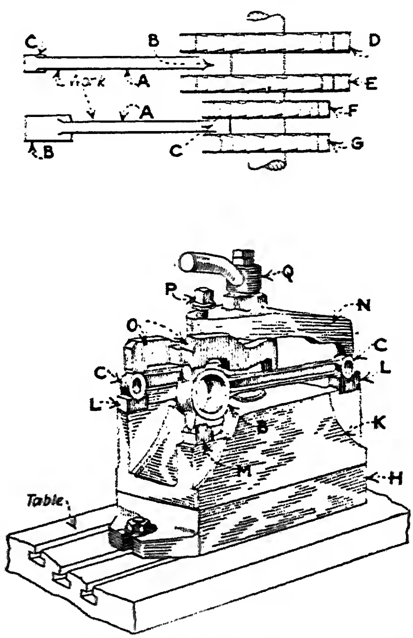


Fig. 174. Double Indexing Fixture for Connecting Rod

at L and M, as shown. The work is clamped by an equalizing device operated by the binder lever Q. The clamp N locks the ends of the rods C and B, while the other ends of the rods are held by the clamp O. The screw P is adjusted so that an equalizing action is obtained.

The table is fed into the cutters so as to mill opposite ends of the two rods, after which the fixture K is indexed and the other end of the work milled. This fixture is an excellent design and is rigid, easily cleaned, and rapid in operation.

Double Indexing Fixture for a Forked Lever.—A very dif-

ficult milling job is shown at *A* in Fig. 175. This is a double-end forked lever of irregular shape which would be difficult to hold and machine if an attempt were to be made to mill each end separately. The work is located in knife-edged V-blocks at *B* and *C* and it is also supported by a single V-block at the

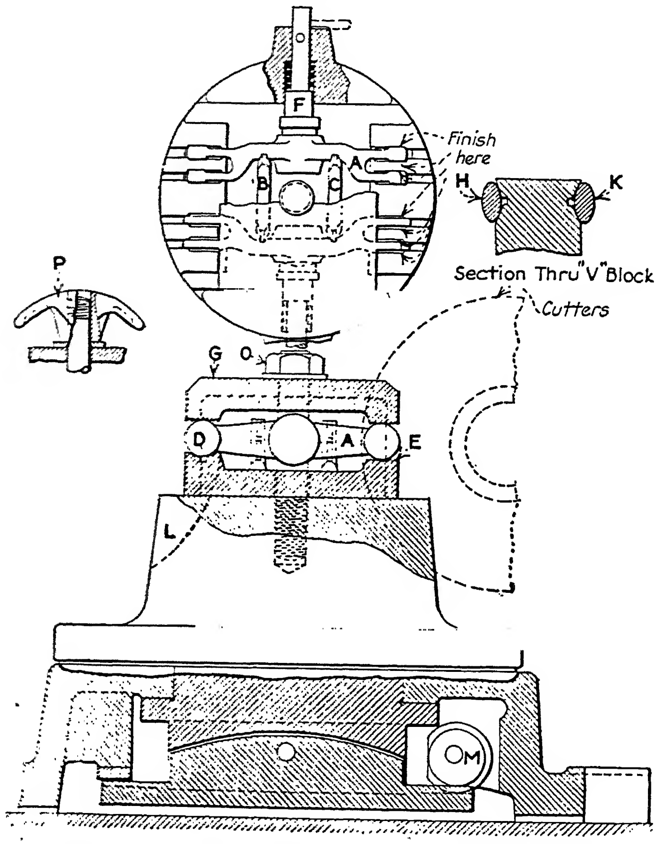


Fig 175. Double Indexing Fixture for a Forked Lever

end *D*, while at the opposite side it rests on a corrugated surface *E*. A spring plunger *F* located at each side of the fixture forces the work into the locaters *B* and *C* while a special equalizing clamp *G* clamps the work down into the V-blocks and corrugated surfaces at the ends of the piece. The shape of the levers at the portions where they locate in the knife-edge V-blocks is shown in the sectional view at *H* and *K*.

The entire locating device is mounted on the indexing table *L* and a mechanism for indexing and clamping is concealed in the base *M*. This indexing mechanism has been previously described and therefore requires no further mention. The clamp *G* can be operated either by the nut shown at *O* or by a hand knob *P*. In either case it is necessary to remove this completely when placing or removing work. Devices of this kind may be found useful for small levers which required milling operations similar to the one shown.

We have previously spoken of the necessity for continuous cutting action when making multiple fixtures. Unless this mat-

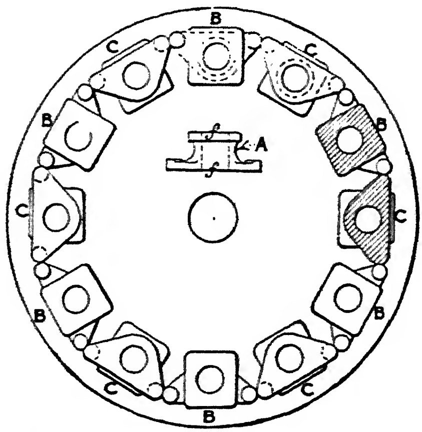


Fig. 176. Economy in Locating Work for Continuous Milling

ter is carefully considered a continuous milling fixture may be made which will not be as economical as a much simpler and less expensive type of fixture.

Fig. 176 illustrates an economical method of setting up the work *A*, the pieces being set up alternately as indicated at *B* and *C* so that only one fixture is used for milling both sides of the work. By so doing the cutting action is very nearly continuous and the expense of an extra fixture is saved. Two revolutions of the table complete all the pieces on both sides. This idea may be used often and the advantages are evident.

It does not always pay to set up large work for circular continuous milling on account of the time wasted in "cutting air" if the pieces are not close to each other. An example of an

excellent arrangement for continuous milling of cylinder heads is illustrated in Fig. 177. The work *A* is located on buttons and jacks as shown at *B* in the sectional view and is clamped against the hardened corrugated blocks *C* and *D* by means of the clamps *E*. The thrust of the cut is taken by the hardened pin at *F*.

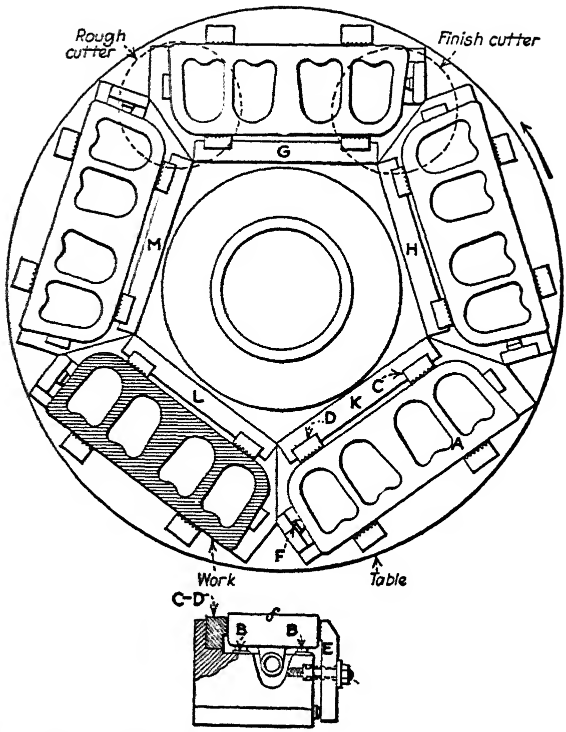


Fig. 177. Continuous Milling Fixture for Cylinder Heads

The fixtures are made up in unit form as indicated at *G, H, K, L* and *M*, and are bolted to the circular table of the milling machine. This example of continuous milling is a very good one as it shows clearly that there is very little space between the pieces so that the cutting action is very nearly continuous. It can also be seen that the cuts are long enough to give the operator plenty of time to remove one cylinder head and replace another. In fact, it would probably be possible for one operator to handle two machines without great difficulty.

Serrating Fixture for Chuck Jaws.—Another application of continuous milling is shown in Fig. 178, in which the cutter acts on the inside of the work. The operation requires a formed cutter as indicated at *A*. The chuck jaws *B* are set up around the fixture, being located on pins at *D* and *E*. The method of clamping should be such that the clamps will not interfere with the cutter.

The requirements for this work are that the inside of the jaw at *A* must be cut to a specified radius and serrated at the same

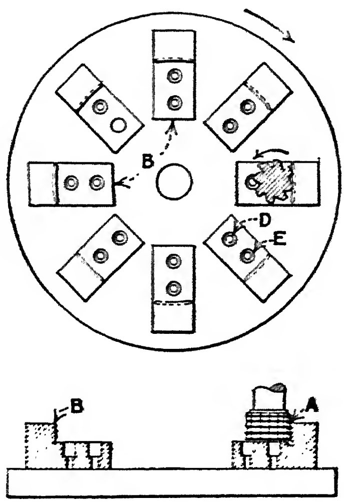


Fig. 178. Serrating Fixture for Chuck Jaws

time. This fixture gives very good results and although the cutting action is not entirely continuous, the pieces are set as closely together as their shape will permit so that in all probability no better arrangement can be made. The work can be set up easily and is produced within the required limits of accuracy.

Multiple Rotary Fixture.—Certain kinds of work permit its being set so closely together that economical production can be obtained by the use of continuous milling fixtures of circular form. An example of this kind is shown in the work *A* in Fig. 179. This piece is to be straddle milled and slotted at the points *B* and *C* as shown in the diagram. The nature of the work is such that the pieces

can be set very closely together and clamped two at a time by means of a binder similar to that shown at *D*. This binder is so arranged that by tightening the nut at *E* the shanks *F* and *G* are clamped simultaneously and in a positive manner. The body of the fixture *H* is a simple ring of cast iron and is bolted to the circular table of the milling machine so that it forms a

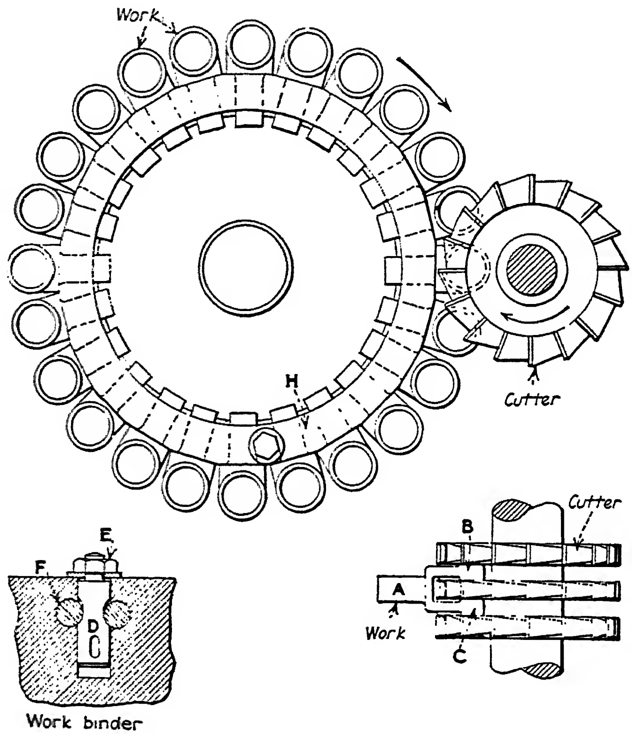


Fig. 179. Continuous Slot and Straddle Milling Fixture

unit with it. It may be argued that the cutter action produces a large radius in the bottom of the slot which is to be milled, but even if this were the case it would not detract from the utility of the fixture. In reality the work *A* is a forging and the points *B* and *C* are relieved so that it is not necessary to cut the entire depth of the slot. This is clearly shown in the illustration.

Continuous Milling Fixture for Pump Body.—Fig. 180 shows a very good arrangement of eight pieces for continuous circular milling of the part *A*. This piece is a small pump body which must be machined on the surface *B* in correct relation to the cylinders *C* and *D*. The work is set up in two knife-edge V-blocks as shown at *E* and the third point of support is ob-

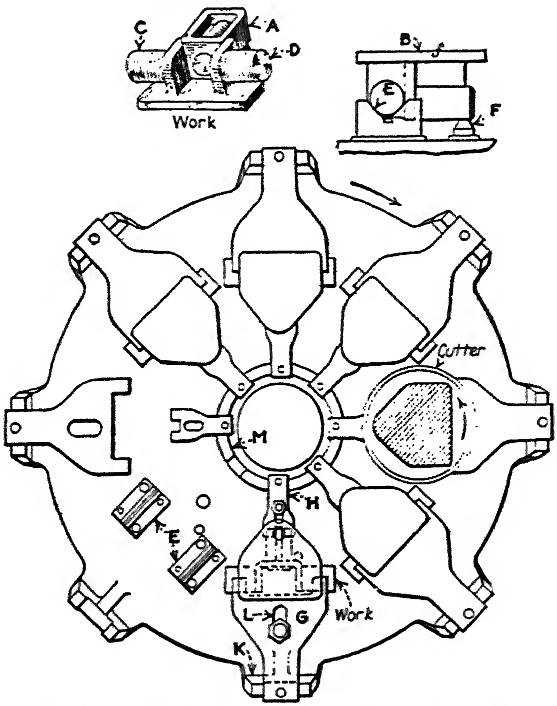


Fig. 180. Continuous Milling Fixture for a Pump Body

tained by means of a hardened stud *F* which makes the setting up of the work approach the ideal condition. The work is clamped by means of the equalizing clamps *G* and *H*, the clamps *G* resting on a support *K* at the outside of the fixture. Provision is made for removing the clamps by the slot *L*, which allows them to be pulled back in order to insert the work. The clamps *H* are also slotted and they rest in a ring *M* at the center of the fixture.

A glance at this design shows that it is symmetrical in its

proportions, and while there is some time lost while the cutter is passing from one piece of work to the other, this amount is not great enough to restrict the utility of the fixture. Obviously, work having a shape like a "piece of pie," or in other words a wedge-shaped piece, usually lends itself readily to the design of a continuous circular milling fixture. Irregular pieces can occasionally be machined to advantage on fixtures of this kind, but often there is a great deal of time lost while the cutter is passing from one piece to another.

High Production Fixture.—Fig. 181 shows a high-production continuous circular milling fixture which was used on a part

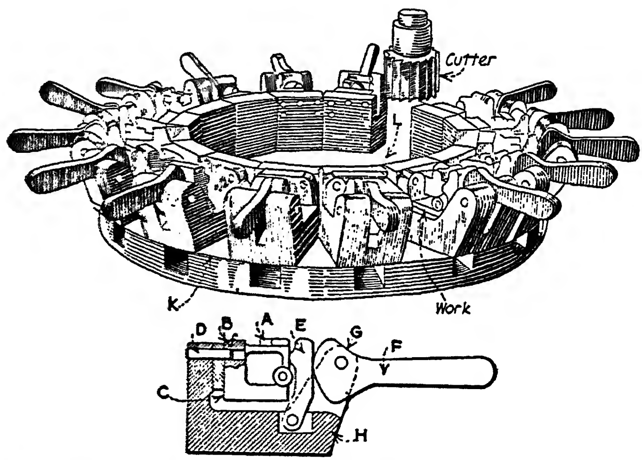


Fig. 181. Continuous Circular Milling Fixture for a Bronze Casting

of the Browning machine-gun tripod. This part is shown clearly in the detail drawing *A* and the portion to be machined is indicated at *B*. The work had been finished on the surface *C* in a previous operation, and the holes reamed so that the pins *D* could be used for locating. The work is clamped by means of the swinging leaf *E*, operated by the cam lever *F*. When removing the work from the fixture the lever stands in a vertical position and allows the clamp *E* to drop back against the surface *G*, thus giving plenty of clearance so that the work can be removed without difficulty.

Unit construction was used in designing this fixture and the blocks *H* are all made up so that they can be located one at a

time on the circular plate *K*. In order to make the illustration perfectly clear one block has been left out at *L*.

In considering the design of this fixture the unit construction should be studied carefully, as its advantages are quite apparent. As a matter of fact, by using this arrangement two

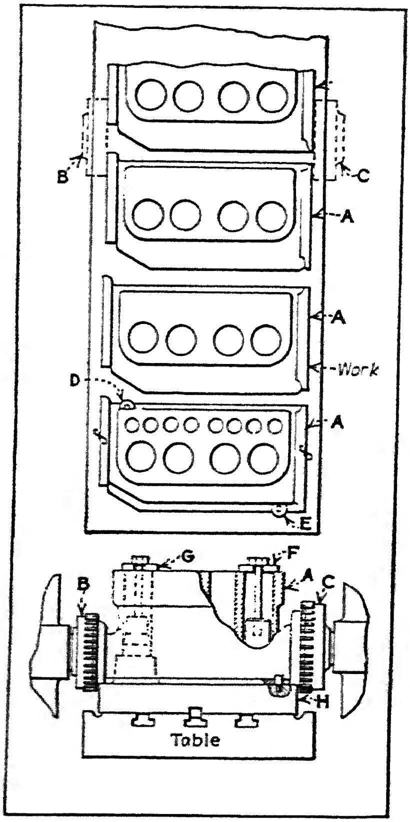


Fig. 182. Continuous Milling Fixture for Duplex Milling

units were made up and used more than a month before the entire fixture was completed. Another point in favor of unit construction is the reduced cost of manufacture, as it is evident that small units can be made up and applied to the fixture much more easily than if they were actually a part of the fixture. Attention is called to the clamping lever and its rapid action.

Not only is it powerful but it locates the work firmly and positively against the seat.

Continuous Milling Fixture for Duplex Milling.—When work is to be milled on two opposite sides as in the example *A* shown in Fig. 182, maximum production can be obtained by setting the work up in series. In the case shown the machine used is a duplex milling machine having large inserted tooth cutters at *B* and *C* and the fixture is designed so that it will hold a number of pieces. Fixtures of this kind are usually made up in units in order that the base plates *H* may not be too difficult to handle when machining. The pieces are located on dowels at *D* and *E* and clamped down by means of heavy clamps at *F* and *G*. These clamps are made U-shape so that they can be removed quickly. The number of pieces which can be machined on a fixture of this sort depends entirely upon the length of the table and it is advisable to use the full length whenever possible in order that the machine may be run continuously for a considerable period of time. The operator is thus able to work two machines if they are conveniently placed so that he can pass from one to the other without loss of time.

After the work has passed by the cutters *B* and *C*, shown in the upper view, the operator can take off those castings which have been machined so that when the entire group of castings has been finished the table can be run back and a new casting placed in position, allowing the machine to be started again without long delay. Then while it is in operation, other castings can be removed and replaced with new ones.

Special Machines for Continuous Milling.—There are on the market a number of machines built especially for the continuous milling of heavy castings. One of these carries its fixtures similar to the arrangement shown in Fig. 182, while another machine has a circular action, the table revolving in a vertical plane. Although these machines are extremely useful for certain classes of production, the writers do not deem it necessary or essential to describe fixtures which should be used on them. The data which have been given here will enable an engineer to design suitable fixtures for machines of the character mentioned in case he is called upon to do so.

CHAPTER VIII

DESIGN OF PROFILING FIXTURES

Principles Involved—Types of Profiling Machines—Cam Milling—Irregular Forms—Methods of Roughing and Finishing—Multiple Fixtures.

The cutting of irregular forms is generally done on a profiling machine or a cam cutting machine. In the manufacture of rifles, pistols, sewing machines, and many other small mechanisms, these machines are used to produce parts which would be difficult to make by any other process. The cutters used for this

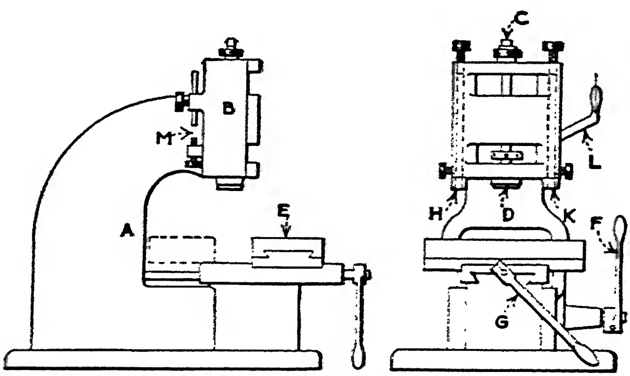


Fig. 183. Type of Bench Profiling Machine

work are milling cutters of various forms to suit the particular piece of work to be manufactured. Profiling machines are, in fact, nothing more than milling machines so arranged that the tables or spindles can be moved freely in any direction. In some cases the table moves in two directions while in others the table is moved in one direction and the spindle in another. Several types of profiling and cam cutting machines are shown diagramatically in this article in order to familiarize the tool

designer with the general principles on which they work. It must be understood that these diagrams are intended only to show principles and are not by any means construction drawings of the machines.

Bench Profiling Machine.—Fig. 183 shows a type of bench profiling machine very useful for small light work. The machine consists of a base and column *A* on which is mounted an adjustable slide *B* carrying a spindle *C*, at the lower end of which, at *D*, the cutter is located. The table *E* is so arranged that it has two movements at right-angles to each other, one of which is obtained by means of the lever *F* while that in the other direction is obtained by means of lever *G*. The work is mounted on the table at *E* and a suitable former is placed in relation to it in such a way that a former pin can be placed in either of the holders at *H* or *K*. The head can be lowered to the correct position by means of the lever *L*.

Provision is made at the rear of the head so that different heights of work can be accurately machined by placing suitable blocks between the adjustable points indicated at *M*. This type of machine is very convenient and does not take up much space.

For the majority of work to which a profiling machine is adapted a single cut is sufficient to produce it within the required accuracy, for which a single spindle profiling machine such as that shown at *A* in Fig. 184 can be used. When work is to be roughed and finished it is sometimes desirable to use a two-spindle machine similar to that shown at *B*. In general construction these two machines are similar, the difference between them being in the number of spindles and former pins utilized.

In the example *A* the table *C* is moved in one direction by means of the handle *D*. The handle *E* moves the head *F* which contains the spindle *G* and the holders for the former pins at *H* and *K*. A lever is provided at *L* to raise and lower the slide *F*. When work is handled on this type of machine, the former can be placed either at the right- or left-hand side of the cutter spindle, according to the nature of the work and the fixture that is being used.

The two-spindle machine shown at *B* is identical in general form with that previously described excepting that there are two spindles *M* and *N* on this machine and three holders having

former pins at O, P and Q. When work is to be roughed and finished in the same fixture, two former pins can be used and a suitable allowance made in setting the pins to provide for the amount of finish required.

It is well to call attention to the fact that the spacing of former pins in relation to the spindle on profiling machines is

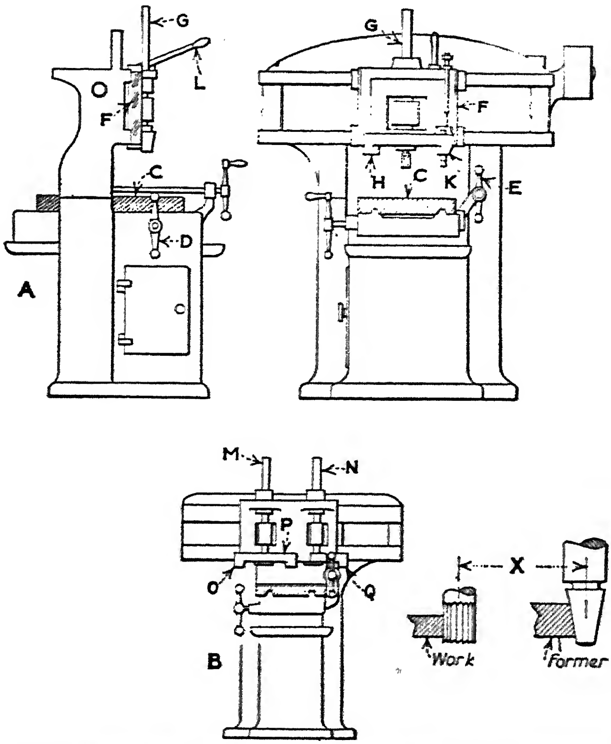


Fig. 184. Diagrams of One- and Two-Spindle Profiling Machines

a fixed dimension as indicated at X. Hence all fixtures must have the work and former plate located in accordance with this dimension. When roughing and finishing cuts are to be taken the allowance between the two cuts is determined by raising or lowering one of the pins.

Cam-Cutting Machines.—Cam-cutting machines belong to the same classification as profilers, although they are usually arranged so that their operation is automatic instead of by hand.

Two diagrams of cam-cutting machines are shown in Fig. 185. *A* shows a general diagram of one machine having two tables, *B* and *C*, on the first of which the former plate is mounted, while on the second the work is clamped in place. The two tables are geared so that they revolve in unison and it is there-

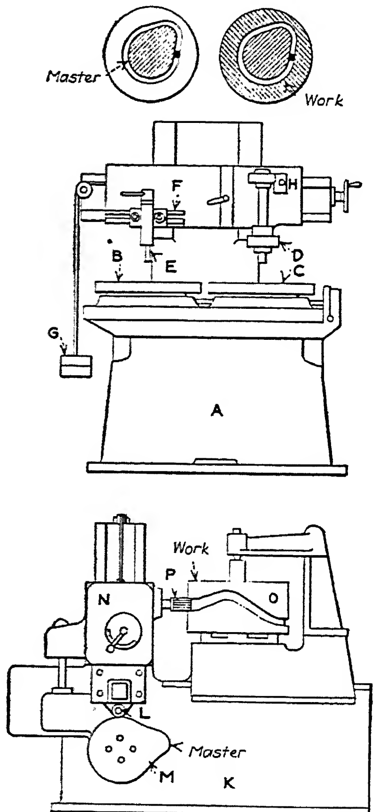


Fig. 185. Diagrams of Two Automatic Cam-Cutting Machines

fore evident that the spindle *D* will follow the form controlled by the pin *E* which can be adjusted along the slide *F*. The weight *G* attached to the carriage *H* keeps the former pin in contact with the former at all times. The action is automatic after the work has been placed in position. By means of suitable attachments, either flat or cylindrical cams can be cut in this type of machine.

Another machine for cutting cams of either cylindrical or plate variety, is shown at *K*. In this case a roller or former pin is placed at *L* so that it remains in contact with the master cam *M* while this is revolved. The revolution of this cam causes the slide *N* to move up and down according to the shape of the master cam. The work *O* is suitably mounted so that it will revolve in unison with the master cam. It is evident that the cutter *P* carried in the slide *N* will be controlled so that it will reproduce a form according to the contour of the "master" used. This machine can be adapted for cutting a plate cam by the use of attachments.

Design of Profiling Fixtures.—In general design a fixture for profiling is one of the simplest, and yet it is very easy for an inexperienced designer to make serious errors, unless he is familiar with the general principles involved in the use of profiling machines. Several important points are given herewith.

(1) General shape of the work. It does not always follow that because a piece of work is irregular in shape it is more profitable to profile it, as it may be found a better production proposition to mill it with a formed cutter. Careful analysis must be made before reaching a decision as to the most profitable way to handle the work. (2) Accuracy required. If a piece of work is to be held within very close limits it is possible that two profiling cuts may be necessary in order to keep it within the required tolerance. If the work is to be hardened and ground, these points must also be taken into consideration and suitable allowances made. (3) Location of work. Provision should be made for locating any work which is to be profiled by drilling and reaming suitable locating holes or by providing other means according to the contour of the work to be machined. When a number of pieces of the same general shape are to be profiled, a single fixture may sometimes be adapted to handle all the work, providing that a standard method of locating is used and that the former plates are made interchangeable.

(4) Position of work. As practically all profiling machines have a fixed relation between the cutter spindle and the former pin, and as the height to which the head can be raised is limited, it is evident that the designer must be careful to keep within the dimensions specified and make suitable allowances so that the work can be removed and replaced without difficulty. Pro-

filing fixtures are usually built very low on account of the limited head movement permitted.

(5) Chip accumulation. Care must be taken in the design of fixtures to see that the former plate is so placed that chips will not get into a pocket and cause inaccuracy in the work. If a slotted plate is used as a former, suitable openings must be provided so that chips can be cleaned out from time to time as they accumulate.

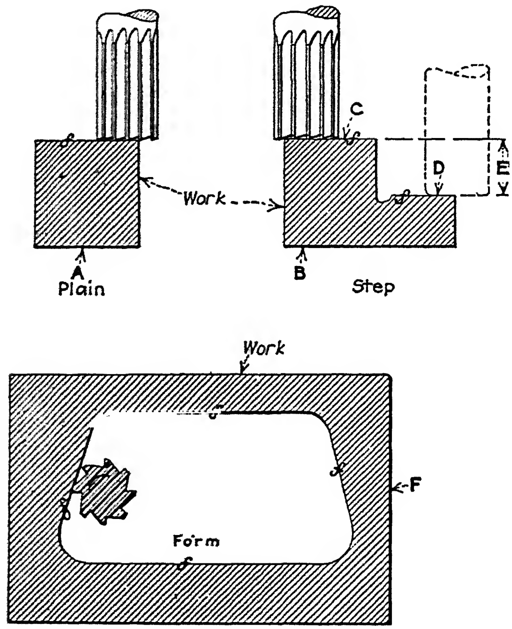


Fig. 186. Several Forms of Profiling Cuts

Forms of Profiling Cuts.—A number of conditions are possible in profiling: (a) There may be a plain simple form on one side of a piece of work; (b) it may be required to cut an irregular form completely around a piece of work; (c) a more or less irregular slot may have to be finished on both sides and this slot may be continuous or it may be interrupted—it may be circular or angular; (d) the inside of a piece of work may be of such shape that it must be profiled to a given form; (e) a series of bosses or surfaces of various heights may require facing.

There are also occasional peculiar cases which cannot be cov-

ered by general notes, but when problems of this kind occur they can usually be solved by application of the various principles which will be mentioned in this chapter.

Fig. 186 shows several varieties of profiling cuts. The work A is a plain surface which is to be profiled instead of milled because there are protuberances on the casting which would make it inconvenient to use a milling machine. Furthermore, the cost of a vertical milling machine suitable for work of this kind is much more than the cost of a profiler, and therefore greater

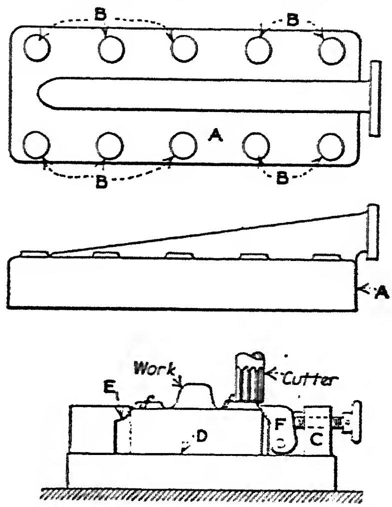


Fig. 187. Surface Profiling

economy is obtained by using the latter machine. The example B illustrates step profiling in which the surfaces C and D are to be held in a fixed relation to each other so that the dimension E will be within certain limits. In machining work of this kind the profiler can be used to advantage by the application of a suitable block between the points noted on the diagram in Fig. 183.

The work shown at F is a plate which is to be profiled inside as indicated by the finish marks. Work of this kind is frequently found in general manufacturing.

Examples of Surface Profiling.—Work similar to that shown at A in Fig. 187 can be handled to advantage on a profiling machine. In this case the bosses B are so arranged that they

cannot be faced conveniently on an ordinary milling machine. On a profiling machine the work can be held in a fixture similar to that shown at *C* and the cutter slide can be locked so that it will remain at a certain height. The operator can very rapidly pass over the various bosses with a cutter as indicated. A simple type of fixture can be designed so that the work locates on the finished surface *D* and is clamped against the locaters at *E* by means of the swinging clamp *F*. Many cases similar to this are found where the profiler can be used to advantage. No forming plate is necessary, as the operator controls the movement of

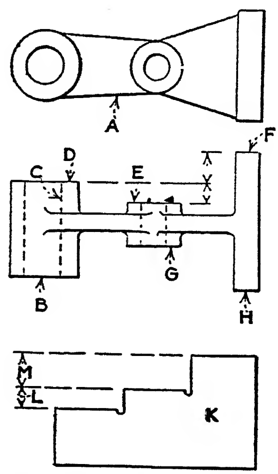


Fig. 188. Step Profiling

the cutter by means of the handles on the machine. In certain cases it may be advisable to provide a guard plate to prevent an accidental movement of the handle which might cause the cutter to gouge into the work, but in most cases this is unnecessary.

Step Profiling.—The profiling machine is particularly useful where several different heights are to be machined on a casting. A case in point is shown in Fig. 188. In this case the work has been previously machined at *B* and the hole *C* has been drilled and reamed. It is necessary to face off the bosses *D, E* and *F* so that they will bear a certain relation to each other. The work is set up on a fixture locating on a plug *C* having shoulders at *B*. Suitable adjustable supports are also provided at points *G* and *H* and the work should be clamped in such a way as not to inter-

fere with the cutter. In milling the various surfaces a step-block can be used like that shown at *K*. The various shoulders are obtained by using the setting as indicated at *L* and *M*.

Fig. 189 shows the application of a step block *A* to a profiling operation. The upper view shows the step block in place on the machine, the various heights for milling being determined by the position of the point *B* which rests on the shoulders of the block.

In the first chapter of this book Fig. 8 showed an operation

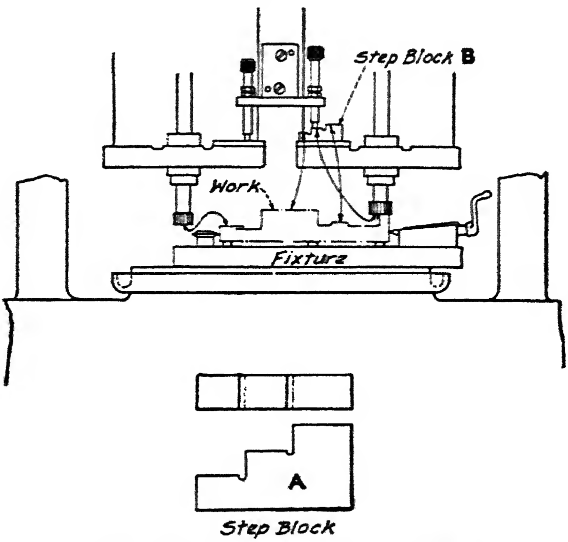


Fig. 189. Application of Step Block

sneet on the part *A* indicated in Fig. 190, and it will be noted by a reference to this sheet that the second operation consisted of surfacing the small end *F* to length and milling one side of small arm *G*. The work is located on a stud *H* and against the previously finished surface *K*. A sliding clamp *L* operated by the thumbscrew *M* straddles the locating plug and clamps the work down firmly. This sliding clamp is located in a block *N* which has a knife-edge on one side as indicated at *D*. The side of the boss *B* is forced against the point mentioned by means of the knife-edge clamp shown at *E;* this clamp being similar in construction to one which was illustrated and described in a previous chapter. The action at this point is shown clearly in

the detail view at *O*. A light spring jack support is used at *P* under the arm *B*. The base of the fixture *Q* is so arranged that it can be fastened with screws to the table of the profiling machine.

When using this fixture the dimension *E* is preserved by using a size block to regulate the difference between the two cuts. This piece of work required extreme accuracy and the fixture shown was designed with great care in order to preserve the relations of various surfaces to each other.

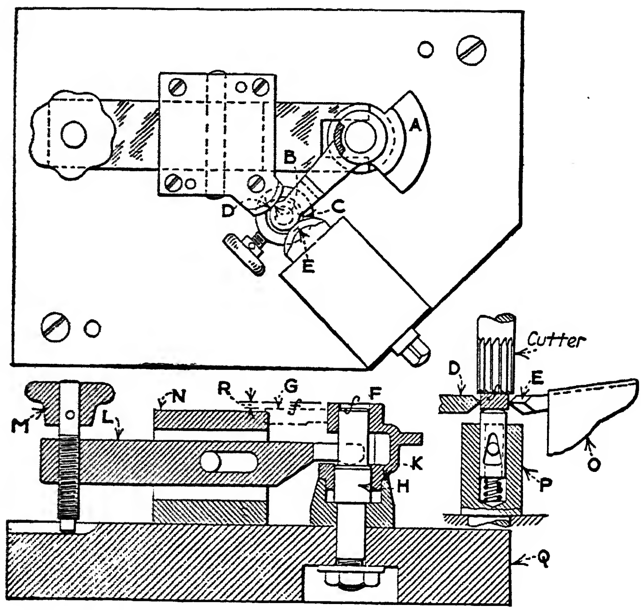


Fig. 190. Profiling Fixture for a Delicate Operation

Slot Profiling.—When an irregular slot is to be profiled it is not advisable to use a cutter exactly the size of the slot which is to be machined. Much better results will be obtained by using a smaller cutter so that each side of the slot will be milled separately. The advantage in using this method is that the cutter diameter need not be held accurately to size, slight variations being compensated for by adjustment of the former pin. In slot profiling it is evident that the cutter must always be smaller in radius than any corner or fillet that is to be profiled. A sharp inside corner cannot be profiled, but it may be cut to

the radius of the cutter and afterward broached, shaped, or filed, according to circumstances.

An example of slot profiling is shown in Fig. 191. In this

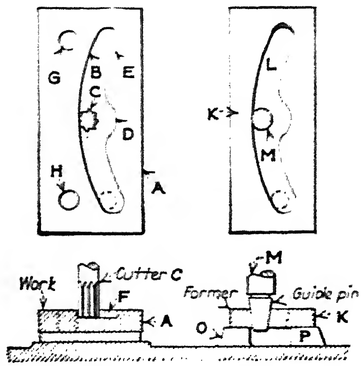


Fig. 191. Slot Profiling

case the work *A* must be machined on the sides *B* and *E* and the recess *D* must also be profiled. The work locates on two dowel pins at *G* and *H*, and is clamped in place by means of

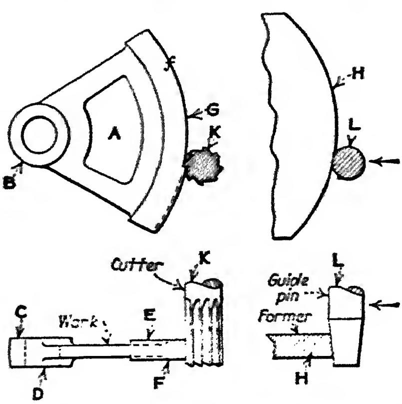


Fig. 192. Circular Profiling Showing Method of Adjustment for Roughing and Finishing

ordinary strap clamps which should be so arranged as not to interfere with the action of the cutter. The slot does not extend entirely through the work but is shallow as shown at F. The former pin *M* controls the movement of the cutter *C* as it is guided along the slot *L* in the plate *K*. This plate is mounted

on bosses at *O* and *P* so that chips will not accumulate in it and thus cause inaccuracies in the work. Openings at the sides allow the chips to be readily cleaned out as they accumulate.

Circular Profiling.—It is sometimes more economical to profile a segment of a circle than to machine it on a lathe, because the lathe operation would be an interrupted cut. An example of this kind is shown in Fig. 192. The work *A* has been previously finished in the hole *B* and also on the sides *C, D, E* and *F*. The radius *G* is to be cut in this operation and the cutter *K* leaves a small amount to be removed by the hob when cutting the teeth. This amount can be regulated by the position

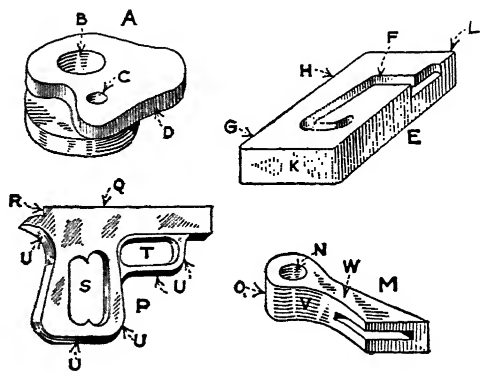


Fig. 193. Examples of Shapes Suitable for Profiling

of the former pin *L* in relation to the former *H*. This method allows the operation to be accomplished much more rapidly than it would be if done on an engine lathe or other similar machine.

Examples of Shapes Suitable for Profiling.—Fig. 193 shows a variety of work requiring profiling operations. The cam *A* is to be profiled on the surface *D*. It has been previously bored and reamed at *B* and the locating pin hole *C* has been drilled and reamed; it is therefore necessary to locate the work both from the center hole *B* and the locating pin hole *C*, and the clamp used must be of such form that the cutter can pass entirely around the work. The natural arrangement for clamping a piece of work of this kind would be by means of a C-washer and nut.

The work *E* is a special cam plate having an irregular slot

in it as indicated at *F*. As this piece has no pin holes on which it could be located, it would be necessary to provide other means of assuring correct location. A natural method would be to place locating studs at the points *G*, *H* and *K* and force the work into position by means of a screw or clamp at *L*. Methods of clamping have been described which could be applied to this piece of work without difficulty.

The pistol frame shown at *P* is an excellent example of a piece of work which requires several profiling operations. The work is located against the finished surface *Q* and also at *R* by means

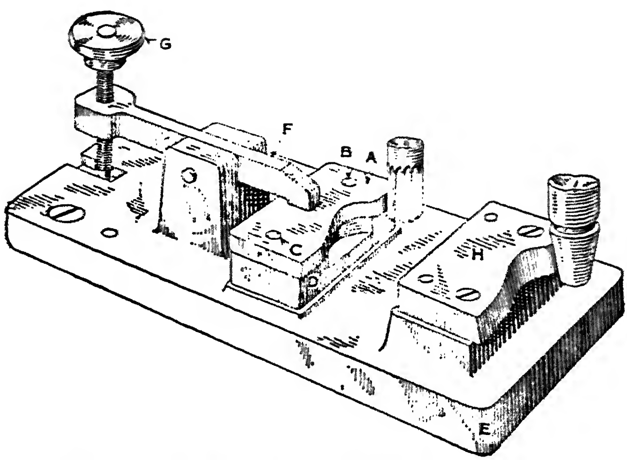


Fig. 194. Example of Well Designed Profiling Fixture

of pins. The operations to be done are profiling of the slots *S* and *T* and the outline *U*. This work can be done by means of a multiple fixture on an automatic type of profiling machine, the fixture for which will be described later in this article.

Another example of a piece of work requiring a circular profiling operation is shown at *M*. This piece has been finished on both sides and the hole has been reamed at *N* so that good location is assured. The operation to be done is the profiling of the round portion *O* and the sides at *V* and *W*. There should be no difficulty in designing a fixture for this piece of work as good locating points can be easily obtained and suitable clamps can be applied without trouble.

Well-Designed Profiling Fixture.—Due to the fact that profiling fixtures are so similar in their general construction, the writers have not attempted to show many designs in this article as many of the principles of clamping and locating that have previously been described can be easily applied to the design of profiling fixtures.

Fig. 194 shows a very clean-cut design of fixture which is not only rapid in its operation but economical in its upkeep. The

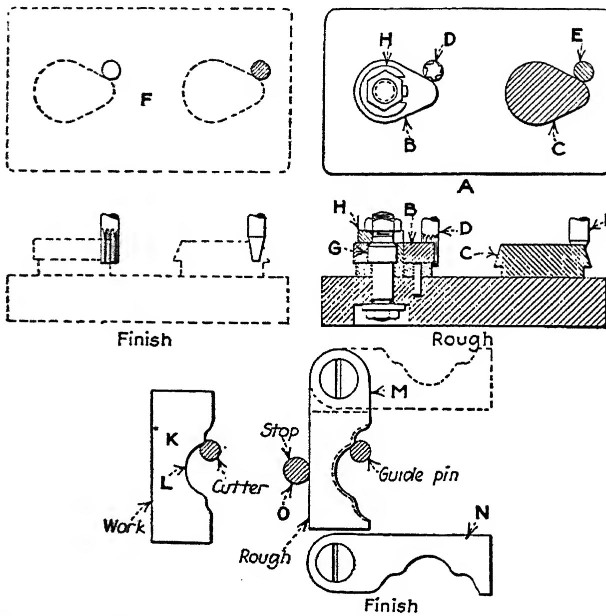


Fig. 195. Diagrams Illustrating Methods Used for Roughing and Finishing Work on Profiling Machines

work *A* locates on dowel pins at *B* and *C*, these pins being set in a hardened plate *D* on the base of the fixture *E*. The work is clamped in place by a sliding clamp *F* operated by the thumbscrew *G*, the clamp being so arranged that it can be slid back out of the way when replacing or removing work. A suitable former is applied to the fixture at *H*.

It may be well to state here that profiling fixtures are usually located on the table by means of dowels and screws and there are occasional cases where a locating slot is also provided on the

table. Factories where a number of profiling machines are used generally standardize their tables both in regard to the slots and also in their relation to screw and dowel holes, so that fixtures made for profiling can be changed from one table to another. A suitable jig is also provided in order to make sure that the hole locations are correct.

Methods Used for Roughing and Finishing Work.—The diagrams in Fig. 195 illustrate several methods which can be used when it is necessary to rough and finish a piece of work at the same setting. At *A* the cam *B* is to be machined, using the former *C* to obtain the correct contour. The cutter and former pin are indicated respectively at *D* and *E*. A two-spindle profiling machine is used for this work, the sliding head of the machine being brought over for the second operation so that the work takes the position shown by the dotted lines at *F*. The sectional view shows the method of locating the work *B* on a stud *G*. The C-washer *H* is used for clamping.

Occasionally a two-spindle profiling machine is not available for doing both roughing and finishing operations on a piece of work. A method which can be used for a case of this kind is shown below, where the work *K* is to be profiled at *L*. It is easily possible to arrange two forming plates such as those shown at *M* and *N* so that they can be successively swung into the position indicated against the stop *O*. These forming plates can be identical in size or they can be made so as to allow the required amount for finish. If they are made the same a vertical adjustment of the head can be made to take care of allowances in roughing and finishing cuts.

Fixtures for Automatic Profiling.—Economies can frequently be effected in profiling operations by using a multiple fixture on an automatic profiling or cam-cutting machine. A fixture of this kind is shown in Fig. 196, the work being an automatic pistol frame, shown at *A* in the illustration. Three pieces are set up on the faceplate *B* which is of special design having a rim around it which serves as a pan so that cutting lubricants can be used, the lubricant running off through a hole in the center of the table. A wire basket catches the chips and allows the lubricant to percolate through and return to the pump.

The type of machine on which this fixture was used is a Pratt & Whitney automatic profiling machine. The former plate

which is generated on the machine from a model of the work, is fastened to the under side of the fixture. It is not shown in the illustration.

It will be seen that each of the parts A locates against pins at C and D, these pins being located in hardened supporting plates. The work is held by the sliding clamps D, the binder handle E being used to pull back the clamps. The construction of these

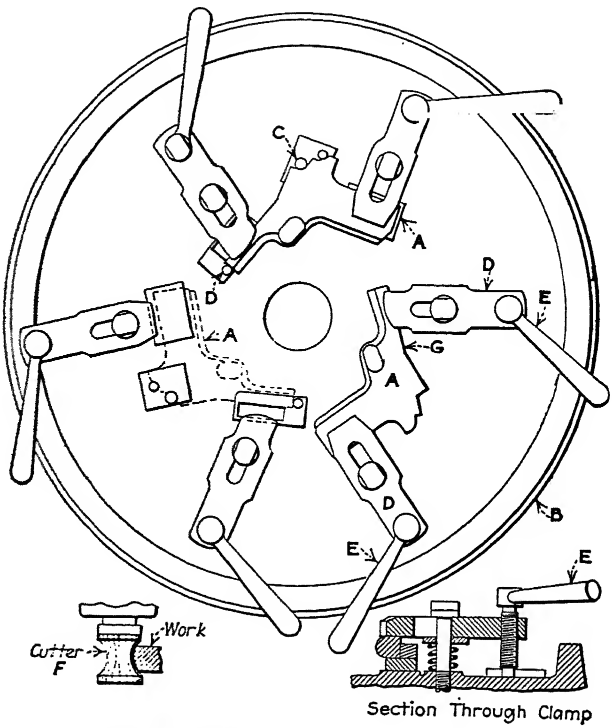


Fig. 196. Fixture for Automatic Profiling

is clearly shown in the sectional view. The cutter F used in this operation is formed in order to produce a rounded surface on the work as shown in the detail view. In order to show the method of clamping and locating more clearly, one of the parts A is indicated by dotted lines and the clamps are shown removed from the work.

Another fixture, of a similar kind but holding 4 pieces instead of 3, is used for the next operation which consists of forming

the surface G. This fixture is not shown but it may be stated that the work is set up so that the four surfaces G form the sides of a square inside of which the forming cutter operates. Fixtures can be designed for automatic profiling when the work is of such a nature as to permit setting up to advantage. Certain forms are more adapted to these machines than others and the adaptability of various machines should be considered before attempting to design fixtures for profiling.

CHAPTER IX

VISE-JAWS AND VISE FIXTURES

SPECIAL AND SWIVEL JAWS—DEVICES FOR INSURING ACCURACY—QUICK OPERATION—DEVICES FOR EQUALIZING PRESSURE—AUTOMATIC EJECTORS.

The use of vises with plain or special jaws oftentimes makes it possible to hold small work advantageously for milling, shaping and drilling operations. Generally speaking vise-jaws are used more often for milling than for other operations. Vises can be adapted and used with special jaws to hold irregularly-shaped work which would be difficult to hold in any other way.

It is unfortunate that tool engineers do not specify the use of vises more frequently, for their advantages are so evident and their adaptability so great that they can be used profitably in many cases which would otherwise require expensive fixtures. The standard type of milling machine vise used for manufacturing in many shops is not adapted for very heavy cutting. It was designed originally for toolroom work to provide a means of holding flat and round stock for light cuts. It is theoretically wrong in principle as the thrust of the cut is taken by the movable jaw instead of by the solid jaw.

Fig. 197 shows a vise of this kind at *A*. Note that the movable jaw *B* is intentionally made long and heavy in order to make it as rigid as possible. In reality, although the vise is not designed for very heavy cutting, good results may be obtained from it and many factories use no other type. The jaw is operated by means of a screw.

The vise shown at *C* is designed especially for manufacturing. This type takes the thrust of the cut on the solid jaw *D*. The movable jaw *E* is a unit with the slide *F* on which the levers *G* and *H* are mounted. By loosening the binding lever *G* and moving both levers along in the slot of slide *F* various openings of the jaws can be easily made according to the capacity of the

vise. In operation the cam lever H is set until the jaws grip the work firmly, after which the binding lever is tightened. As the latter is slightly eccentric to the cam lever, the locking action is improved and greater leverage obtained. Both of the vises illustrated can be furnished with special and swivel jaws.

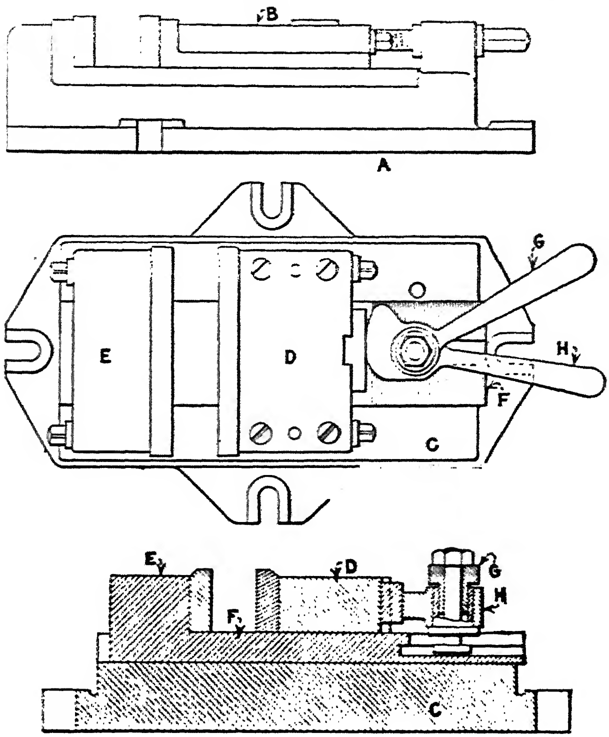


Fig. 197. Examples of Milling and Manufacturing Vises

In addition to the two types of vises shown there are special forms for toolroom use. The vise principle used is generally like that shown at A, the difference in design being in the method of mounting the vise so that it can be swiveled in either a horizontal or vertical plane. A manufacturing vise operated by compressed air was described in a previous chapter.

Special vises can be made up for extraordinary conditions if it is found that standard vises cannot be used. If it is impossible to grip the work properly with special jaws in a standard

vise, the designer can apply the same principles to his design and make a special vise to suit the conditions. When the capacity of a standard vise is not great enough to take in the work, a special vise can be designed providing the production required warrants the expenditure. Vises that are made up specially are apt to be costly, yet if they are to be used for high production the expense will be saved many times.

Design of Vise-Jaws.—Vise-jaws are apparently very simple from the designers' standpoint, yet their importance is appreciated more as a better understanding of their adaptability and possibilities is gained. A few points of importance are given here in connection with the use of vise-jaws.

(1) Selection of vise. Most factories use several styles and sizes of vises in their production work. Data should be provided regarding the capacities of the various types in order that a selection may be made with discriminating judgment. The predominating factors which influence the selection are: (a) The depth of the jaw: (b) the maximum opening; (c) the length of the jaw.

(2) Depth of the work. As most vise-jaws are made shallow, the depth of the work to be held is an important factor in determining whether a vise can be used for a given operation or not. Within certain limits it is possible to design the jaws for a special piece of work so that they will extend above the jaws of the vise, but when this is done they should be made substantial enough to withstand the thrust of the cut and the pressure of the vise screw without vibration.

(3) Length of the work. The length of vise-jaws varies according to the type and size of machine vise selected and it is often desirable to hold a piece of work that is considerably longer than the jaw. It may also be necessary to provide some means of location beyond the end of the jaws. It should not be decided that a piece of work is unsuitable for holding in vise-jaws simply because the work is longer than the jaws.

(4) Vise opening. When vises are screw operated, special jaws should be so designed that very little movement of the screw is necessary to release the work, allowing it to be taken out of the jaws without difficulty. In cases where the work locates on pins in one or the other of the special jaws, it is frequently necessary to provide a filler or clamping plate which

can be thrown out of the way when the jaws are released in order to avoid too much movement. This matter will be taken up in detail later in this article.

(5) Formed jaws. Irregular work such as small forgings, castings and other parts which require milling operations are frequently held by means of special jaws which are "formed out" by the toolmaker to fit the contour of the work. When jaws of this kind are designed, a clamping action must be obtained on the work close to the point where the cut is to be made. For example, in a forging having a ball end, the jaw

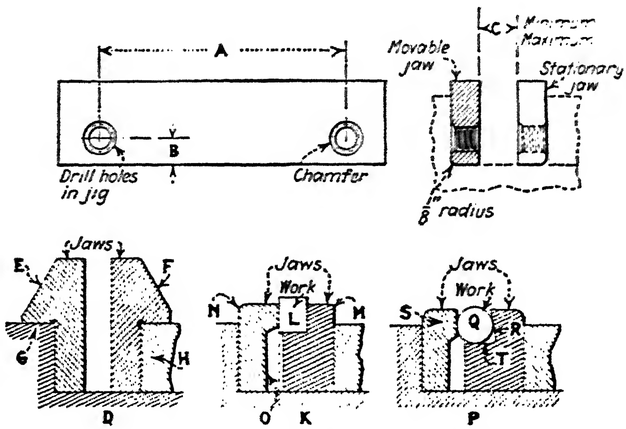


Fig. 198. General Diagrams of Vise-Jaws

would be formed to hold the ball loosely in order to obtain the location, while the work would be gripped at other points where the cutting action is to take place. There are so many varieties of formed jaws that it has not been deemed essential to take up their design in this article. Each individual case must be treated differently according to the shape of the piece and the general requirements of the work.

General Diagram of Vise-Jaws.—Fig. 198 shows a standard type of vise-jaws, such as are usually supplied with a milling machine vise. Attention is called to the fact that the dimensions *A* and *B* are fixed, according to the style and size of the vise used. It is necessary therefore to ascertain these dimensions before proceeding with the design of any special jaws. The dimension *C* is also important as it determines the maximum size

of the work that can be properly gripped between the jaws of the vise.

It frequently happens that the work is higher than the height of the jaws, in which case care must be taken to see that the pressure is resisted by designing the jaws so that they will have additional support near the point where the cutting action is applied. An example of this kind is shown at *D* in which it will be noted that the jaws extend considerably above the body of the vise as shown at *E* and *F*. Support is provided by the "heel" at *G* and *H*.

The example at *K* indicates a method used for locating the work *L* on one jaw *M;* the other jaw *N* is cut away as shown at *O* to prevent trouble from an accumulation of chips. The principle used here is applicable to many kinds and shapes of small work, the location always being on one jaw only.

A good method of holding round work is shown at *P*. The work *Q* lies in a "vee" which is slightly undercut at *R* so that the pressure of the jaw *S* tends to draw it down against the surface *T* thus holding it firmly in position. This principle can be used to advantage in holding many kinds of round work.

Assuring Accuracy in Location.—When work is to be milled accurately in relation to some previously finished surface it is oftentimes advisable to provide vise-jaws with an accurate means of location. This is particularly desirable when the vises used are old and more or less worn, but whether this is the case or not a very high degree of accuracy can only be obtained by making some provision in the jaws so that they will always register exactly the same. If the tolerances on the work are very close, this point must be kept in mind when designing special jaws.

Fig. 199 shows a very good method of registering vise-jaws accurately. *A* and *B* are the two jaws, one of which is provided with hardened guide pins at *C* and *D* while the other contains bushings *E* and *F*. The pins act as dowels and thus preserve the correct relation of the jaws at all times. In such a case the work might be located on suitable pins at *G*, the positions of these pins being determined by the nature of the work and the general requirements. The length of the dowel pins is determined by the thickness of the work and the method of location. The side view of the jaw gives a clear idea of the relative positions of the screw holes *H* and *K* and the dowel pins mentioned.

Two other methods are shown in the same illustration. In one of these the work *M* rests on the shoulder of a special jaw *O* while it is gripped by the other jaw *N*. A support is provided at *P* which acts in a somewhat similar manner to the dowels previously mentioned by preventing the movable jaw from lifting when it is tightened. These jaws would be improved by giving them a shoulder at *Q* and *R* similar to the case shown previously. One objection to this design is that the spaces at *T* and *S* are narrow and therefore they form an excellent place for chips to accumulate and cause trouble in closing the vise.

Another example of an *attempt* to provide an accurate means

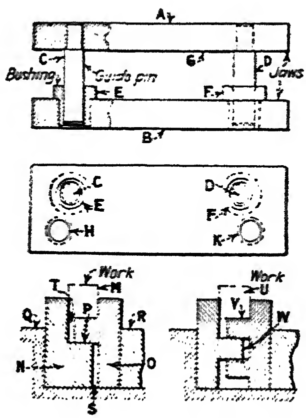


Fig. 199. Assuring Accuracy in Location

of location is shown in the jaws holding the work *U*. In this case the work rests on the shoulder *V* and a tongue is provided at *W* which is intended to prevent the jaw from lifting and thus obtain greater accuracy than would be otherwise possible. The objection to this type is that it is more or less expensive; there are bad pockets for chips and it is generally impractical.

In analyzing the methods of location shown in this illustration it is obvious that the guide pin method is the best on account of its adaptability, simplicity in construction, and the ease with which the jaws can be cleaned. The cost of construction and the accuracy obtained are additional points in its favor.

Quick Removal of Work.—When making up a set of vise-jaws it must be remembered that the rapidity with which the

vise is operated is dependent to a great extent on the amount of opening necessary to remove and replace the work. When the latter is of such a nature that it must be located on a stud and removed from the stud after the operation, a considerable opening to the jaws may be required. When a cam operated vise is used a certain amount of opening can be made rapidly, and this may serve to take care of many conditions, but when the regular type of milling machine vise is used, every half revolution of the screw means that the operator is obliged to remove his wrench and replace it again. This takes time and is a decided objection if the jaws need to be opened rapidly. In order to obviate this trouble it is customary to provide a

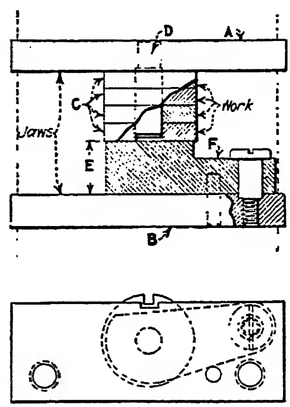


Fig. 200. Provision for Quick Removal of Work

filler block to lie between the work and one jaw. By taking out this filler block the work can be removed and replaced readily and not more than a half turn of the screw is required to provide sufficient opening. The filler can be made in the form of a loose piece or it can be pivoted to one jaw so that it can be swung out of the way when not in use.

Fig. 200 shows a pair of jaws at *A* and *B*, the jaw *A* holding four collars *C* by means of the locating block *D*. If no provision were made for rapid removal of the work it would be necessary to open the jaws the distance shown at *E* in order to allow all four collars to be removed at once. To provide against such a contingency, the jaw *B* is provided with a swinging block *F* which acts as a clamp against the work and yet is quickly re-

movable. The designer is advised to make provision of this kind in all cases where similar work is to be handled. Although it is permissible to use a loose piece for the same purpose, it is not nearly as good as a swinging member.

Swivel, Multiple and Floating Jaws.—When rough work is being held by being gripped on two or more surfaces, it is advisable to provide a swivel jaw in order to hold it properly. Also when several pieces are being held at the same time there is a possibility of slight variations in thickness or diameter of

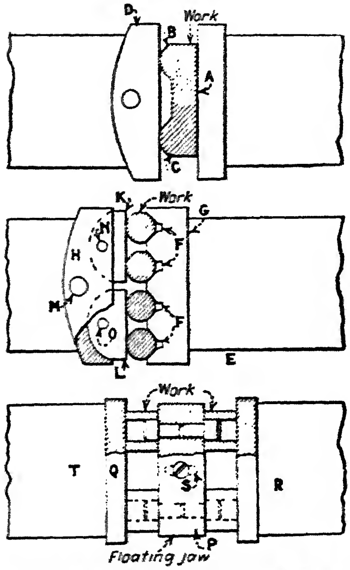


Fig. 201. Swivel, Multiple and Floating Jaws

these pieces which makes it necessary to provide some means of distributing and equalizing the pressure.

Fig. 201 shows a piece of work at *A*, being held for a milling operation. The lugs at *B* and *C* are likely to vary somewhat in height, therefore provision must be made for this by means of a swivel jaw as shown at *D*.

An example of a swivel jaw arranged so that it will hold four pieces is shown at *E*. In this case the work consists of four bars *F*, located in the V-block jaw *G*. The other jaw *H* is made in the form of a swivel block having two supplementary swivels at *K* and *L*.

The designer should remember that all of the pressure of the jaws will come upon the pins at *M*, *N* and *O* if made like the illustration. It would be much better practice to make the pins mentioned a loose fit in the swivel and let the pressure come against the radius at the back of each of the blocks. The pins should only act as retainers and not take any pressure.

A supplementary or floating jaw is sometimes used to hold several pieces, as shown at *P*. This method is useful where several pieces are to be milled at one time. The block lies between the two jaws *O* and *R* and is located by means of a pin in an elongated slot shown at *S*. In operation, the work is loaded by removing the floating jaw *P* and placing the piece on it after

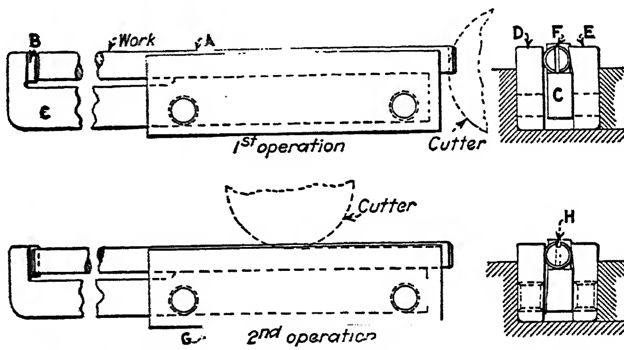


Fig. 202. Method of Locating and Holding Long Work

which it is set in position between the jaws and clamped in place. This method is useful for handling small pieces of work when a number of them are to be located at one time. If there is likely to be a variation in the length of the pieces, the jaw *Q* can be made in swivel form to take care of the variations.

It is sometimes possible to use the same set of jaws for more than one operation on the same piece of work, and when this can be done without interfering with the production schedule it is obviously an advantage. Occasionally jaws can be provided with two sets of pins or other means of location and cutters can be arranged on the arbor so that both operations can be done at the same time; one piece being finished while the other is being rough-milled. When bar work is to be milled it is often possible to use the same jaws for several operations. An example of this is shown in Fig. 202, in which the work *A* is a bar

somewhat longer than the jaws in which it is being held. The bar is located endwise by the stop at *B*, this stop being a part of the extension *C* which is fastened to one jaw. An end view of the jaws is shown at *D* and *E*, where it will be seen that the jaw *E* is slightly undercut to assist in holding the work. The locating bar *C* is fastened to the jaw *E* and acts as a support for the work as indicated.

The first operation consists in cutting a slot in the end of the bar at *F*. The locater *B* is made so that it will fit this slot,

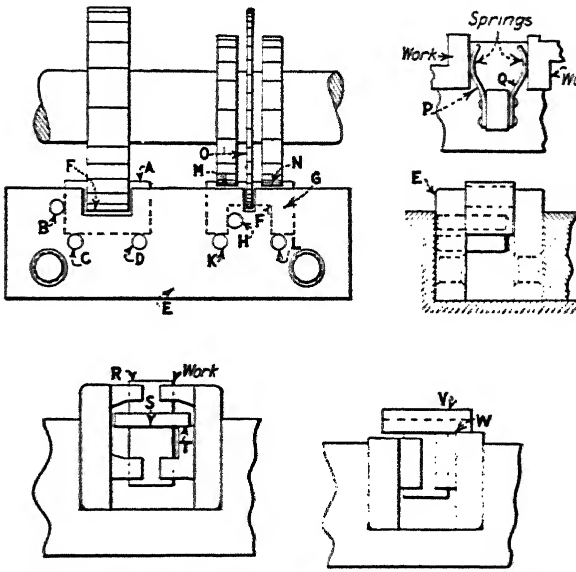


Fig. 203. Examples Showing Methods of Location

therefore not only can the work be set up for the second operation with the same set of jaws, but the second operation will be properly located in relation to the first. The second operation consists of milling a longitudinal slot in the bar as shown at *H*.

Location of Small Work.—In locating small work in vise-jaws, a great deal depends upon the shape of the piece. Fig. 203 shows an excellent example of a production job on a small piece of work on which two operations are being performed at the same time. The work *A* is located on pins at *B*, *C* and *D*

in the jaw E while the slot is cut at F. This is the first operation on the work after it has been cut off. In the same set of jaws the piece is held in another position as shown at G and located by the milled slot F, using locating pins at H, K and L. This operation mills the slots at M and N and also cuts the work into two pieces by means of the slotting cutter O. As it is possible that the work might not be located firmly against the two pins at B and H, provision is made to insure their contact at these points. By using a pair of flat springs at P and Q the work will be automatically forced over against the locating pins without particular attention on the part of the operator.

The work shown at R must be located from the shoulder S. This brings up a point in design which is frequently neglected when vise-jaws are made and that is the alignment of the jaws. It is always advisable to make the shoulder location on one jaw only as shown at T, rather than to attempt to line up two shoulders on opposite jaws. Another example of a shoulder location is shown at V, in which case it will also be noted that the location is on one jaw only. There are occasional cases when this rule can be overlooked, for example, when dowel pins are used in the jaws to insure accuracy as shown in Fig. 199. However, it is safer to follow the rule of locating on one jaw only.

Vise-Jaws Designed for Several Consecutive Operations.—It is interesting to note the adaptability of vise-jaws for holding small parts which have several consecutive milling operations. An example which illustrates this point is shown in Fig. 204. The consecutive operations are shown on the rectangular block in the illustrations 1, 2, 3 and 4. The work is first cut off from a rectangular bar so that it takes the form 1. The next operation is the forming of the radius shown at 3, and the fourth operation is the profiling of the circular cut shown at 4-A. In the first operation the bar B is placed in the jaws shown until it strikes the end stop C. The jaws are then tightened and the portion D is cut off. When the jaws are loosened the piece slides down the inclined plane E into a box provided for it and the bar B is pushed forward again until it strikes the stop C, after which the cutting-off operation is repeated.

In the next operation the work is held by means of the jaws F and G while the straddle milling cut is made at H and K. This operation machines the piece to length, a suitable allow-

ance having been made for this operation while cutting off the work.

The next operation is the cutting of the radius as shown at *L*. The work is held by suitably formed jaws and is located against the pins *M*, *N* and *O* by means of the thumbscrew *P*, which is so placed that it is outside of the milling machine vise and can therefore be easily manipulated. These three examples have

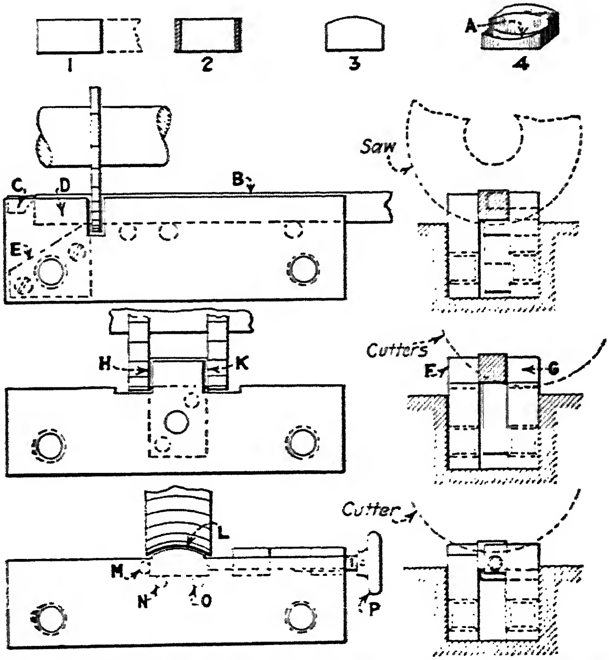


Fig. 204. Vise-Jaw Design for Several Consecutive Operations

been given to familiarize the designer with the methods used for progressive operations on small parts. Many applications can be made of the principles shown here.

Equalizing Pressure by Means of Beeswax Jaws.—There are instances when a number of pieces are to be held at the same time in a set of vise-jaws and yet it is difficult to make sure that all of the pieces are held firmly, due to slight variations in the work. There are also irregular forms which have to be supported at several points while cutting, and which must in-

corporate some method of equalizing the supports to take care of slight inaccuracies in the work. The principle shown in Fig. 205 can be applied to a variety of conditions, and it has been used successfully for holding work which would be difficult to support by any other known method. In the example shown there are five parts *A, B, C, D* and *E,* located in V-blocks in the jaw *F*. The other jaw is equipped with a series of plungers *G* which are lapped to an accurate sliding fit in the jaw *H*. The chamber *K* in this jaw is filled with beeswax or heavy grease. When this mass is compressed by means of the screw at *L* the vise pins *G* are forced out until they all come in contact with

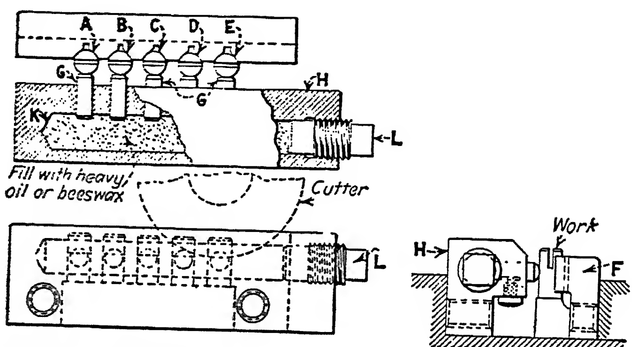


Fig. 205. Equalizing Pressure by Means of Bees-Wax Jaws

the work. After the first adjustment has been made by means of the screw the pins will automatically equalize themselves so that a positive contact will be assured on each one. In making up a set of jaws of this sort care must be taken that the various fits for the pins and the screw are carefully made in order to prevent leaks when the pressure is applied.

Vise Fixture for Small Work.—Occasionally a milling operation has to be performed on a piece of work which is difficult to locate in vise-jaws. When a condition of this kind arises it is sometimes possible to design a vise fixture in which the work can be located and clamped and then the fixture itself placed between the vise-jaws for the milling operation. A case in point is shown at *A* in Fig. 206. This piece of work has previously been drilled and reamed at *B* and *C* and faced on both sides. It is located on two pins in the holes and clamped by means of

the strap clamp *D*. This clamp is so arranged that it swings away from the work until the pin *E* strikes the stop pin *F* in the body of the fixture, thus permitting the work to be removed. When the work is clamped the point of the screw *G* rides up on the angular surface of the block *H* and a wedging action takes place which makes the operation very rapid. The fixture *K*

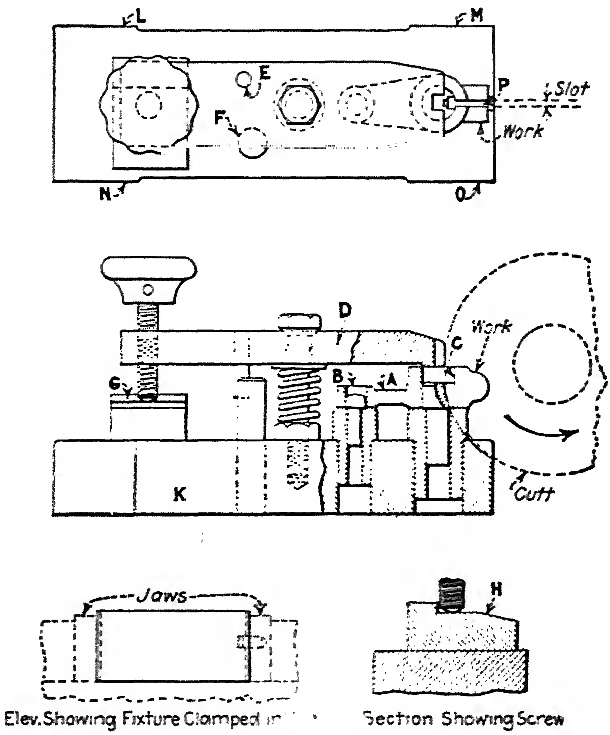


Fig. 206. Vise Fixture to Hold Small Work

locates between the jaws of a standard vise which clamps it at the points *L*, *M*, *N* and *O*. Provision is made at some convenient point so that end location in the vise-jaws will be assured. The operation to be done in this fixture is the cutting of the slot at *P*. Obviously this method of holding is convenient and at the same time the fixture is cheap and can be operated rapidly. Cases are found now and then when a fixture of this kind can be used to advantage.

Special Vises with Equalizing Jaws.—As a vise of suitable dimensions to handle the work *A* shown in Fig. 207 could not be obtained, a special vise was designed. The work is located by means of two pins at *D* in the solid member of the vise. The work to be done is the cutting of the two slots *B* and *C*.

The swivel block *E* fits the radius at *F* in the sliding member which passes under the rigid block *G*. The pin *H* acts as a retainer only and is a free fit in the hole. In operation the cam lever *K* acts against the hardened block *L*, clamping the work firmly. The body of this vise is made of cast iron and the sliding parts are all carefully fitted to insure the necessary accuracy. It will be noted that construction of this vise is such that the cutting action comes against the solid member and not against the movable jaw.

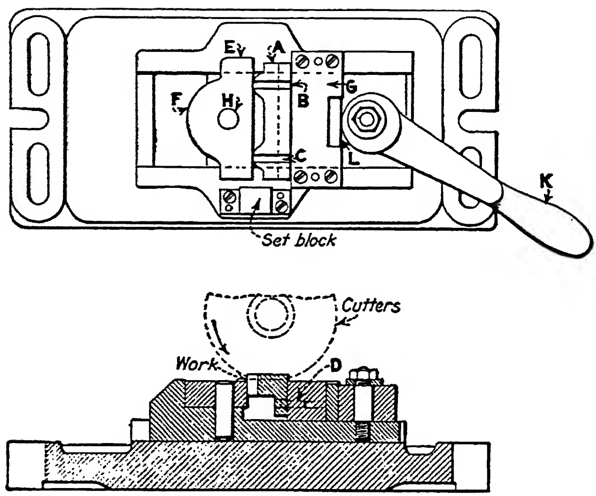


Fig. 207. Special Vise with Equalizing Jaw

There are occasional cases when special vises can be made up to suit a particular condition but unless the conditions are such that the expense of a special vise is warranted, it is better to use a standard vise.

Ejectors for Vise Jaws.—As a refinement in the design of vise-jaws it is often necessary to provide means for removing the work after the milling operation has been done. Many times the shape and position of the work is such that it can only be

removed with difficulty. For cases of this kind ejectors can be provided which will facilitate the operation. Several examples of ejectors are shown in Fig. 208. The work *A* is to be located on the stud *B* in the vise-jaw *C*. As it would be difficult to locate this work easily it is placed on the movable jaw *D* so that

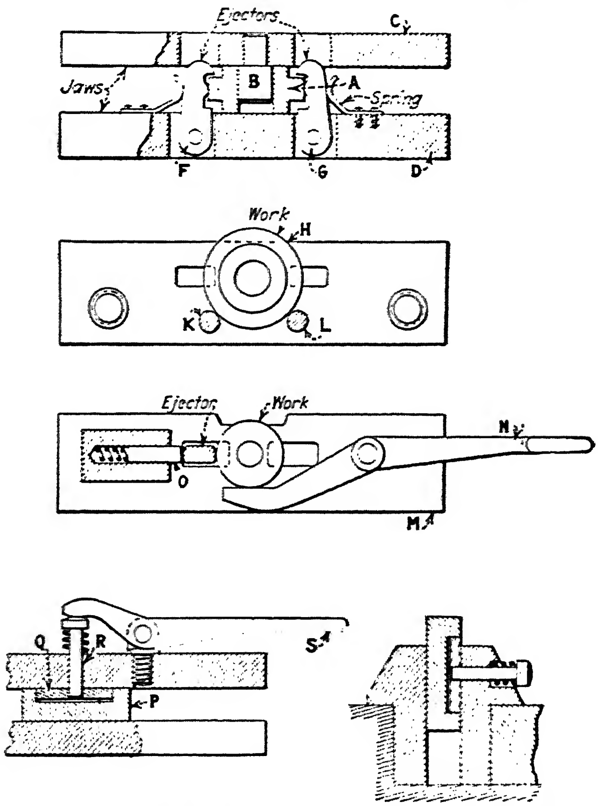


Fig. 208. Various Types of Ejectors for Vise Jaws

it rests on the two pins at *K* and *L*, which locate it approximately. Then, as the jaw is moved up into position the beveled end of the stud *B* enters the hole, thus locating the work correctly. After the work has been done, the ejectors *F* and *G* pull the work away from the stud, making it easy for the operator to remove it. This method precludes the necessity of using a screwdriver to pry the piece off from the stud, which

might result in damage to the work or spring the stud out of alignment.

The form of ejector shown at *M* can be used either by itself or in connection with a piece of work like that at *A*. Assuming that this work is the same as the other piece except that it is smaller and thinner, it would be difficult for the workman to get his fingers into position to remove the work. Ejectors similar to those shown at *F* and *G* could be used here to pull the work off from the locating stud, but after it had been removed it would still lie in the jaw in such a position that the workman could not get hold of it easily. By making use of the lever *N*, however, the piece could be raised so that it would be easily accessible.

Attention is called to the construction of the plungers *O* which provide the spring pressure for the ejector. This method is entirely different from the other and it has some advantages, although it is a little more expensive in construction. There is no danger of this type of spring plunger being clogged up with chips or dirt.

The work *P* is located on a button at *Q* and it will be seen that such a piece might be difficult to remove after it had been machined. Using the lever *S* to operate the plunger *R* makes the operation much easier and the work can be removed without difficulty.

In the design of vise-jaws, particularly when small and thin pieces are to be handled, the ejector is an important factor as it assists greatly in cutting down the operating time. In addition to this, the work can be removed readily and without injury and as there is no necessity for hammering or otherwise injuring the fixture, a better product is assured.

CHAPTER X

BROACHES AND BROACHING FIXTURES

Principles of Design—Tooth-Spacing and Chip-Clearance—Burnishing—Keyway Broaching—Multiple Fixtures—Index Broaching—Spiral Broaching.

The process of broaching is very old and dates back several hundred years when holes of various shapes were made in metal by forcing one or more tools of the required shape through the work by driving with a hammer or other means. Later on, short broaches with teeth were made and pushed through the work by means of hand presses or those operated by power. It was not until 1901, however, that the present process of pulling broaches through the work was developed. Before this time broaches were pushed through the work; now they are pulled through it in the majority of cases.

Push broaches are short while pull broaches are long and it is evident that the latter types possess distinct advantages over the former, in that a greater number of teeth can be used. and as a consequence the cutting action is more uniform and sizes can be held much more easily. In addition to this, broaches that are pulled through the work do not tend to "run" or crowd to one side or the other, which fact is also a decided advantage. We must qualify this statement somewhat, because a dull broach will run out of alignment more or less. If the pull broach is sharp, however, it should run true if properly used.

Important Points in Design.—There are a number of factors which influence the design and general construction of broaches and broaching fixtures. The tool engineer who attempts the design of tools of this sort must first familiarize himself with the important features and method of operating a broaching machine. There are several types on the market, the general features of which are more or less similar. Different methods of centralizing the broach in relation to the work are used, but

other than this the construction is much the same in all types. In the horizontal types of machines, the work rests or is held by a fixture of some sort against a vertical faceplate through which the broach passes while in operation. Some types of broaching machines have only one spindle while others have two. In the two spindle variety one spindle is operating while the other is returning so that the lost time in setting up is reduced to a minimum.

Let us now consider the various points of importance in connection with the design of fixtures for broaching and also some pertinent matters regarding the broaches themselves:

(*1*) *Material To Be Broached.*—As in other machining operations, the material to be broached is an important factor in determining what tools are best adapted for the work. So, in broaching, the material affects not only the design of the broach but the fixture that is to be used as well. The shape of the broach teeth and the amount of material that each tooth will have to remove are important factors which influence the production.

(*2*) *Thickness of the Metal.*—This matter is of great importance in broaching operations as it affects the spacing of the broach teeth. It is difficult to cover the situation in a general note but detailed information will be given on the subject later on in this article.

(*3*) *Production Required.*—This matter must always be taken into consideration in designing a fixture as the cost of tools should be as nearly as possible in proportion to the amount of work that is to be produced. In broaching fixtures, this factor may easily affect the design of both broach and fixture and also determine the type of machine on which the work should be done.

(*4*) *Preparation of Work Before Broaching.*—Unlike many other operations, work that is to be broached usually requires a certain amount of preliminary machining. A hole must be provided in which to insert the broach and a square surface should be provided on that side of the work which locates against the faceplate of the broaching machine. This point is of importance and, unless due consideration is given to it, may affect the accuracy of the work to an appreciable extent.

(*5*) *Accuracy Required.*—It is seldom that a broached hole is required within an accuracy greater than from 0.001 to 0.002 in.

and as it is not particularly difficult to keep within these limits it is evident that the broaching process can be applied to many kinds of work in general manufacturing. If very close tolerances are required both roughing and finishing cuts can be taken as in other machining processes. In some cases it is necessary to locate a broached hole in relation to another one which has been previously machined, in which case it may be found desirable to use the outboard sliding support with which broaching machines are provided in order to support the end of the broach and keep it in correct alignment while in operation.

(6) *Lubrication.*—All broaching machines are provided with means of directing a stream of cutting lubricant into the hole while it is being broached, and this must be considered in making up a fixture in order that the lubricant may reach every part of the broach. For example, a square hole should be broached with a corner upward and not flat, so that the lubricant will reach all four sides of the broach and will not spatter off as it might otherwise. In broaching splined work, the channel between two of the splines should be at the top, so that it will retain the liquid and serve to carry it into the hole with the broach. The kind of lubricant used depends upon the material that is to be cut.

(7) *Rigidity.*—It is highly important that all work that is to be broached should be supported properly in order to preclude the possibility of "chatter" or of the material springing away from the broach during the process, which would cause inaccuracies and tend to injure the broach. When several pieces are to be broached together or when the work is thin, particular attention must be given to the method of holding. Suitable supports or jacks must be provided for work which is irregular in shape in order to avoid any of the troubles mentioned.

(8) *Clamping.*—Various types of clamps have been described in previous chapters so that it is only necessary to refer to some of these to cover practically all conditions of clamping such as may be required in broaching fixtures. Particular attention should be paid to any work which is thin or of irregular shape so that there will be no distortion due to improper methods of clamping.

(9) *Cost of Tools.*—Usually the fixtures used for broaching are simple in design and inexpensive to make. There are cases.

however, when something more elaborate is needed in order to decrease the setting up time or when the work is of such a character that it cannot be supported and clamped properly in a simple type of fixture.

Broaching Methods.—In considering the design of broaching fixtures, the designer must first realize that there are two methods in use. Fig. 209 illustrates diagrammatically both forms of broaching processes. The work shown at *A* is set up on the table of an arbor press at *B*. The broach *C* is short and is pushed through the work by means of the press spindle. Attention is called to the fact that all push broaches must be short and that the usual method is to push several of them through the work, one after another, each one being so proportioned that it will

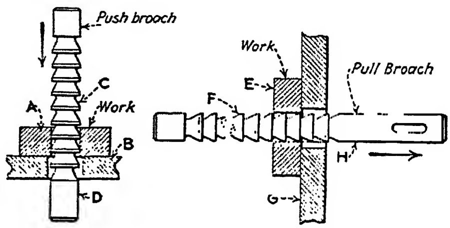


Fig. 209. Types of Broaching

remove a little more stock than the one which preceded it. The end *D* should be so made that it will act as a pilot when entering the work. The teeth are so proportioned that each tooth is slightly larger than the preceding one. The amount of this variation is dependent upon the material to be cut and the shape and size of the hole.

The piece of work shown at *E* is broached by pulling the tool through the work instead of pushing it as in the first instance. This work is done on a horizontal broaching machine designed strictly for the broaching process. In contrast with the other example shown, the broach *F* is long, usually from 24 to 36 in., depending on the capacity of the machine and also upon the amount of stock to be removed. It will be noted that the pulling action of this broach is resisted by the faceplate *G* on the machine itself. The portion *H* acts as a pilot and centers the broach in the hole, as in the preceding example.

Broaching an Oil Groove.—A bushing which acts as a shaft bearing is often provided with an oil groove. When the work

is manufactured in small lots a cold chisel of the proper form is frequently used and the operation is done by hand. If the production is large, other methods can be used according to the depth of the groove, the material which is to be cut, and the machines which are available.

Fig. 210 shows a piece of work *A* in which an oil groove is cut at *B*, this groove being shallow as indicated in the illustration. In this case the work rests on a bushing *C* and the ma-

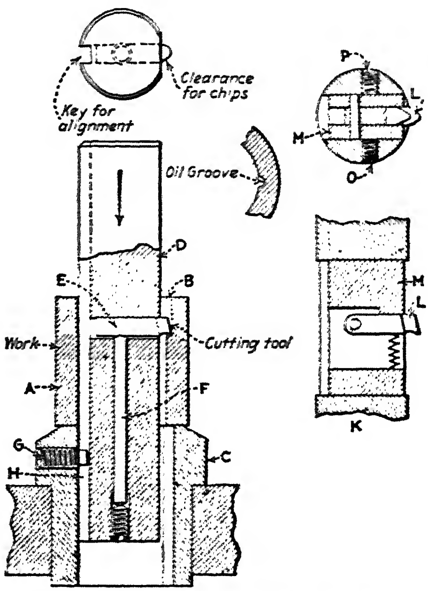


Fig. 210. Simple Broaching Operation

chine used can be an arbor press or other similar machine. It might be possible to use a drill-press spindle to apply the pressure if no other machine were available. The cutter or broach bar *D* is a sliding fit in the bushing and an adjustable cutter is provided at *E*. By means of the screw and binding shoe *F* the cutter can be held in any position desired.

The bar itself is located in the bushing by means of the teat screw *G* which enters the slot *H* in the bar. It is evident that the depth of the groove is controlled by the position of the cutter, and there may be cases when two or three cuts are needed in order to produce the desired results. Oil grooves are usually

shallow so that a single cut will often be found sufficient. In the event of a deep cut being required, it would be better to run the work through several times, adjusting the cutter a little more for each successive cut, rather than to attempt an adjustment several times on each piece of work. It would be possible, however, to make a bar with rapid adjustment features if this seemed desirable.

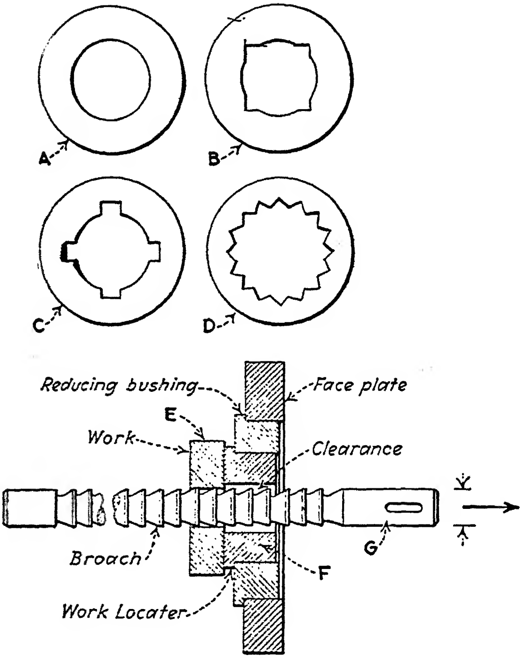


Fig. 211. Examples of Plain Broaching and Methods of Setting Up

A method of this kind may be found useful occasionally for work that is being rushed, or when production is such that the expense of a broach of the regular form is not warranted. This process can also be used for high production if the cut is very shallow, in which case certain refinements may be found advisable. A bar can be made in such a way that the upper end is held in a drill press spindle, and the cutter L mounted in an adjustable block M, as shown in the sectional illustration at K. The block can be held by setscrews as at O and P in the upper

view. After the cutting has been done the drill press spindle is raised. The cutter rubs lightly against the groove during the movement, but does not injure the work.

Plain Broaching.—Certain varieties of work that are to be broached do not require fixtures of any kind, although occasionally bushings may be necessary if the work is small. In Fig. 211 are shown several examples of work which require nothing but a bushing large enough to admit the broach. Example *A* is a cylindrical piece in which the round hole is to be broached after it has been drilled; *B* is a square hole broaching proposition; *C* is a four keyway; *D* is a collar having a number of inside serrations.

Each one of these pieces can be broached without fixtures by using the method shown in the diagram. The work *E* may be any one of the pieces illustrated above, and it may be seen that the only thing which must be provided except the broach itself, is the bushing *F*. Even this is unnecessary if the work is of sufficient diameter so that it will rest firmly against the faceplate on the machine. The broach is so made that the portion *G* acts as a pilot in the work, thereby centering it so that as soon as the first tooth strikes the work it is drawn back against the faceplate and held there during the cutting action.

A number of matters must be taken into consideration in the designing of broaches for various purposes. Some of these points have been taken up under another heading in the first part of this chapter. There are others, however, which cannot be properly covered in a general way, therefore these will be mentioned specifically.

A few examples are given in Fig. 212 in order to make some of these points clear to the tool designer. The work *A* has been properly prepared for the broaching process by drilling a hole and facing one side square with the hole. It will be seen that this piece of work is not very thick so that if a broach were to be used such as that shown, only one tooth of the broach would be cutting at a time. In other words, the distance between *B* and *C* is too great so that the work may drop down—off center—and thus either break some of the broach teeth or produce work which is off center or otherwise inaccurate. Two or more teeth of the broach should always be in the hole at the same time, and yet there should not be too many to allow for clear-

ance for chips. As there is no way in which chips can get out from between the teeth until they reach the end of the hole it is evident that an accumulation is likely to clog the broach, causing breakage or rough work.

The example *D* shows a long hole and it can be seen that there are too many teeth engaged in the work at the same time. It is advisable therefore in designing broaches for long holes, to

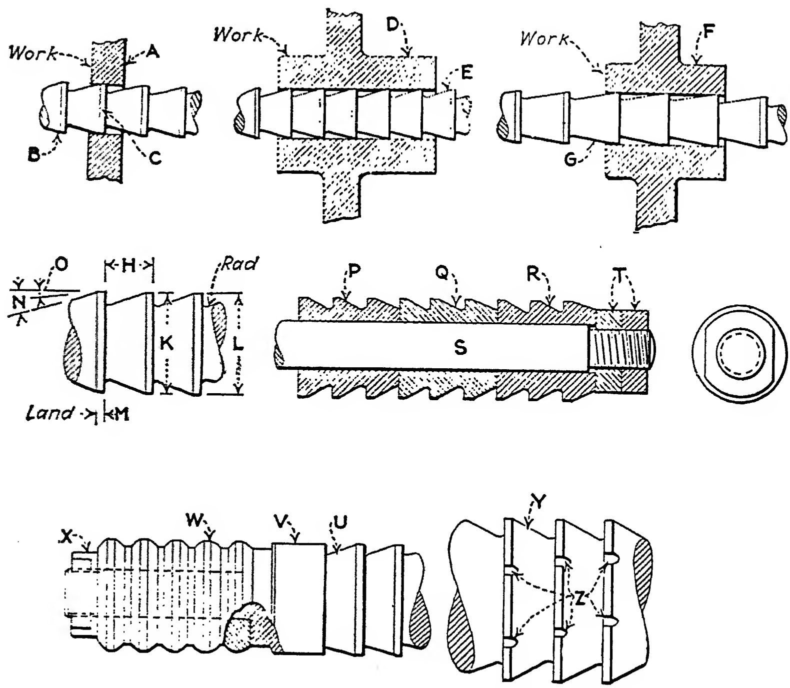


Fig. 212. Principal Points in Broach Design

space the broach teeth farther apart than when the work is thin. The example *F* shows a good arrangement in which there are always two and sometimes three teeth in the hole at the same time as indicated at *G*. There is plenty of chip clearance, however, so that the cutting action is good and the work produced will be both accurate and smooth.

It can readily be understood from the foregoing discussion that a broach of the same diameter may not always be suited to two different pieces of work if one happens to be thick and

the other thin. This objection can be overcome if the work can be arranged or stacked two or three pieces at a time. If the condition is similar to the one shown at *A*, suitable provision must be made for clamping the various pieces together so that they cannot drop down on the broach during the operation.

Spacing of Teeth and Chip Clearance.—The diagram of the broach at *L* illustrates the points that are of importance in designing broaches. The *pitch* of the teeth is the distance between them as indicated at *H;* the amount of variation being determined by the material to be cut and the length of the hole. A formula which is often used for determining the correct distance, is here given. Assuming *P* as the pitch and *L* as the length of the hole, then: $P = \sqrt{L} \times 0.35$. This formula can be considered as reliable for average conditions and it will serve as a basis on which the designer can determine the correct pitch for any given condition. As a general thing, very large broaches which will permit a deep space for chips can be designed with a decreased pitch, while those broaches which are to be used for tough or hard materials may require a slightly increased pitch.

The variation in the size of successive teeth is indicated at *K* and *L;* this amount, ranging from 0.001 to 0.003 in. for steel and sometimes double this amount for soft cast iron and brass, is influenced by the length of the hole to be broached so that too great an amount of metal may not be removed by a number of teeth in engagement at the same time. The *land* on the teeth is indicated at *M*, the amount usually being about 1/32 in. for medium sized broaches. The land on the teeth is sometimes ground straight but ordinarily there is a back taper of from 2 to 3 deg., as indicated at *O*.

N indicates the clearance, which depends largely on the length of the hole to be broached and the amount of metal which each tooth is to remove. It is also affected by the diameter of the hole as previously mentioned. An important point in this connection is the fillet at the root of the tooth. This should be made as large as possible, both for strength and also so that there will be less likelihood of cracks during the hardening process.

Plain Broaches.—Plain broaches are usually made with the last few teeth the same size in order to assist in the upkeep of the tool. After grinding a few times the number of teeth of the

same size will be gradually reduced until finally there is only one sizing tooth left, after which nothing further can be done and the broach must be discarded or used for a smaller size after re-grinding. Some forms of broaches can be made up in a series of units as indicated at *P, Q* and *R,* and mounted on an arbor *S.* It is evident that the units can be provided with a keyway for location and they can be held on the arbor by means of check nuts as shown at *T.* If the size of the broach permits, it is as well to put the nuts on the forward end and provide a shoulder at the rear for the various cutters to be drawn against. The size and method of coupling used have an effect on this part of the design.

Broaching Round Holes.—When round holes are to be broached, a good finish can be given to the work by burnishing it or swaging it as shown at *U.* In this case a burnishing broach *W* of rounded form is drawn up against the shouldered portion *V* by means of the nut at *X.* After the cutting has been done the rounded portion is pulled through, thus producing a very fine finish and also compressing the metal so that a hard wearing surface is obtained.

Broaches having considerable area often can be made to cut more freely by nicking the teeth as shown in the diagram at *Y.* The nicks must be so arranged that they overlap each other as at *Z.* An arrangement of this kind breaks up the chips and assists in cases where hard metal is encountered or on broad surfaces.

Broach Couplings.—The method of connecting the broach to the pulling member of the broaching machine permits the operation of coupling and uncoupling the broach to be done rapidly. Provision of some sort must also be made so that either the work may be adjusted vertically in relation to the broach, or that the broach itself can be adjusted in relation to the work. Sometimes the faceplate is adjustable up and down and in other cases the broach coupling is provided with adjustment.

In Fig. 213 is shown a piece of work *A* and a broach *B,* the latter being connected to the pulling member of the broaching machine by means of the taper pin *D.*

The coupling slide *F* is mounted on the ways of the machine and suitably fastened to the screw *E.* The holder *C* screws into slide *G,* which can be adjusted by means of screw *H,* so as

to bring the broach into the correct position with relation to the work.

Methods for Slotting the Ends of the Broach.—The detail at *K* shows a common method of slotting the end of the broach when a pin coupling is used like that shown above. Another method is indicated at *M*, this arrangement consisting of a milled slot on each side of the bar. There are occasional instances when it is desirable to pull more than one broach at a time in a horizontal plane and when this becomes necessary it is obvious that some other form of coupling must be used. A case in point is shown at the lower left-hand corner of the illus-

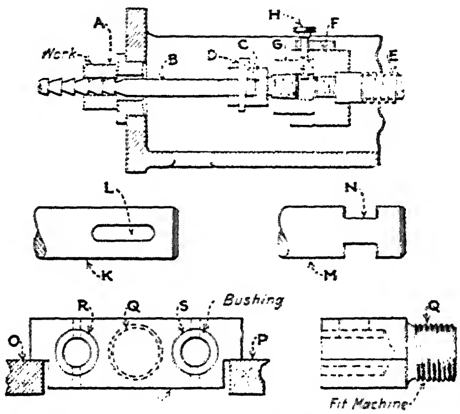


Fig. 213. Methods of Broach Pulling

tration, the coupling member *X* being mounted on the ways of the machine at *O* and *P*. The screw portion *Q* fits the pulling member of the machine, while the broaches are held in the usual manner at *R* and *S*. In such a case care must be taken by the designer to see that the pulling action is distributed equally on both broaches so that there will be no chance of cramping during the operation.

Keyway Broaching.—Several examples of keyway broaching are shown in Fig. 214. The ordinary method is illustrated in the example *A*, which is being cut by broach *D*. The work is located on a bushing *B* which is fastened into the faceplate of the machine. This bushing is so made that the broach fits a slot in it at *C*, thereby guiding and supporting it at the same time.

This method is generally used for ordinary keyway cuttting as the only fixture required is the guide bushing. Standard broaches can also be used, which is obviously economical.

When a taper hole has a keyway cut in it as shown at *E*, the method used is the same except that the guide bushing *F* is made to fit the taper and it is also tilted so that the keyway will be parallel to the side of the tapered hole as indicated. Care must be taken by the designer to see that the work fits the tapered portion *H* yet does not strike against the surface *G*. Sufficient clearance must be provided so that there will be no

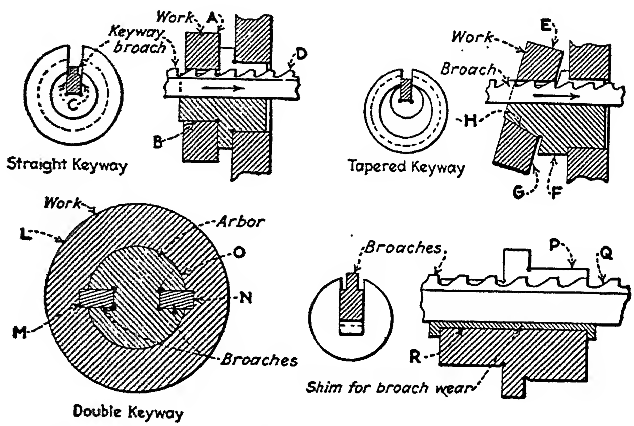


Fig. 214. Various Methods of Broaching Keyways

chance for this to happen; 1/16 or even 1/8 in. is none too much, depending on the angularity of the taper.

An excellent idea which can be applied to certain kinds of work is shown at *P*. This is a guide bushing in which the broach *Q* is operating. It is evident that as the broach or bushing wears, the keyway will become shallower and eventually will not be deep enough to pass inspection. By providing a shim at *R*, adjustments can be made as desired by placing paper or thin metal between the shim and the body of the bushing, thus raising it up and prolonging its usefulness.

Referring to the work shown at *L*, attention is called to the two keyways at *M* and *N*. In broaching a piece of work like this two methods are possible; a bushing can be made like that at *O* and two separate broaches used at *M* and *N*, in connection

with a coupling like the one illustrated in Fig. 213, or a broaching bar can be made up with two inserted broaches in their correct positions, and the work done without resorting to a guide bushing. Either of these methods will produce good work.

Broaching Square Holes.—In broaching square holes the work must first be prepared for the operation by drilling a hole and facing one side square with the hole. As a general thing the corners are not quite square, as a sharp corner would be hard to keep up and also it might cause trouble in hardening

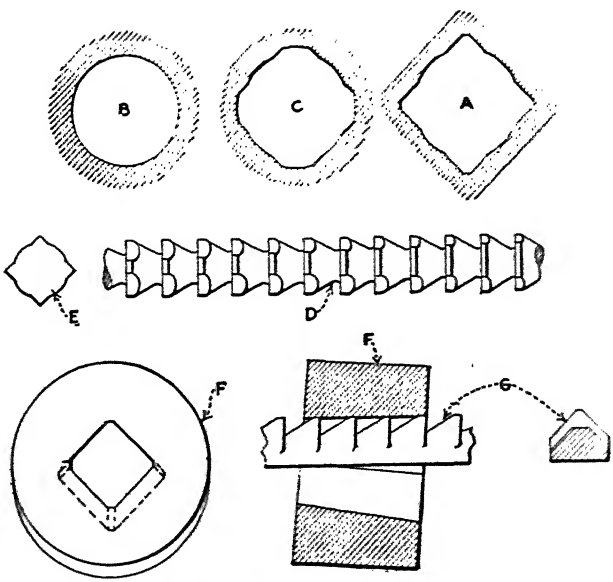


Fig. 215. Broaching Square Holes

if the work were to be heat-treated. The sides of the hole are also relieved slightly in order to obtain a better bearing on the shaft and likewise to relieve the cut somewhat while broaching. This is clearly shown in the work *A* in Fig. 215. Starting with the hole at *B*, the work when about half finished would appear like the diagram at *C*. The illustrations at *D* and *E* show the general form of broach used for this kind of work. The method used for setting up the work is the same as those mentioned and shown under the descriptions of broaches which do not require guide bushings.

When a square tapered hole is to be broached the work must be set up so that the taper of the corner of the hole is parallel with the spindle of the machine as shown at *F* in the same illustration. An indexing fixture must be made for work of this kind and the broach itself must be so designed that it is of the form shown at *G*. The cut should extend slightly beyond the center of each side. It is of the greatest importance for the designer to remember that the angle at the corner of a square taper hole is not the same as the angle of the sides. It is a

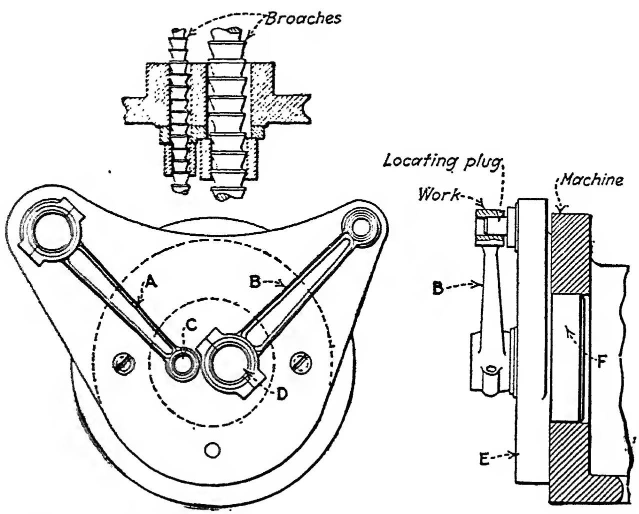


Fig. 216. Double Broaching Fixture for Two Different Size Holes

compound angle which is not usually given on the blue print of the part; therefore it must be figured out by trigonometry.

Broaching Fixture for Connecting Rod.—The crank pin and piston pin holes in connecting rods for automobiles are frequently finished by broaching. A fixture for this purpose is shown in Fig. 216. The fixture itself is very simple and yet it is effective and accurate. The two connecting rods *A* and *B* are located on studs at their upper and lower ends, one large end and one small end of each rod being broached at the same time as indicated at *C* and *D*. The locating plugs are correctly located in the faceplate *E* which is positioned by means of the plug *F* against the faceplate on the machine. A large and small

broach are used simultaneously, after which the connecting rods are transposed while the other two holes are broached.

Broaching Fixture for a Ratchet Sector.—Fixtures for broaching use many of the devices which have been previously illustrated and the principles of holding and clamping can be

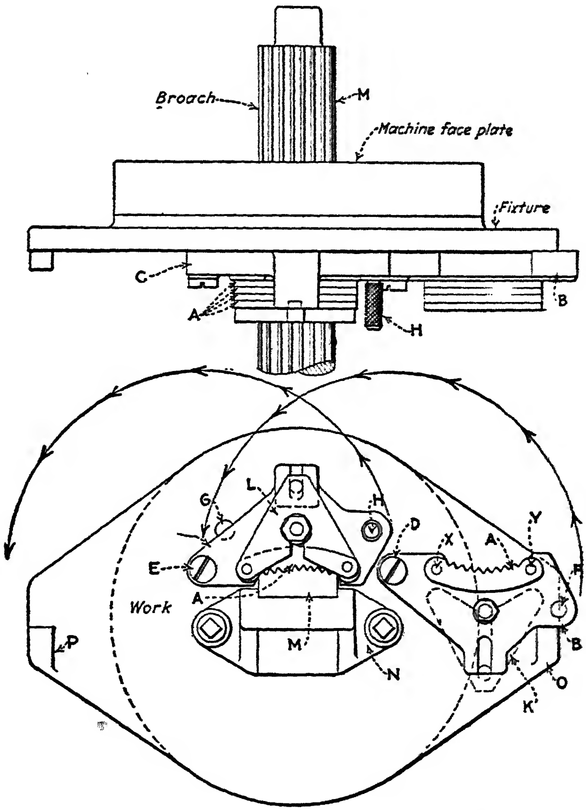


Fig. 217. Broaching Fixture for Ratchet Sector

applied to this type of fixtures as well as to the others. There are, however, peculiar conditions to be met in the design of fixtures for broaching and these can best be appreciated by citing suitable examples. The matter of removing and replacing the broach after each operation sometimes takes time which can be avoided by a little thought on the part of the designer. An example of this kind is given in Fig. 217, the work *A* being a

ratchet sector of which four pieces are to be broached at a time as indicated. The work is set up in the swinging locater *B* which rests on a lug *O*, and is pivoted at *D* in such a way that it can be swung over into the broaching position when desired and located by a pin at *F* which corresponds to *G* on the face-plate as shown. In the loading position, the clamp is pulled back as shown by the dotted lines at *K* while the work is being placed on the two pins at *X* and *Y*. The clamp is then tightened and the work is ready to be swung into place when the other pieces are finished. While the loading of one group of pieces is proceeding the other set is being machined, being held in the other swinging member *C* and located by the dowel pin at *H*. The clamp *L* holds the four pieces firmly and the broach *M* cuts the serrations shown. A bracket *N* is mounted on the face of the plate to act as a guide and support for the broach. After the pieces have been machined the swinging member *C* is turned over until it rests on lug *P* where the pieces can be removed and replaced by others.

As the broach used for this operation is a heavy one it is advisable to support the outer end on the sliding support which can be obtained as a part of the broaching machine equipment. With a fixture like the one shown, however, it is unnecessary to remove the broach at all and consequently the only time lost is in the return stroke of the broach and the swinging into place of a fresh group of pieces. Arrangements of this kind are sometimes possible when work does not have a hole in it through which the broach must pass.

Broaching Fixture for Timing Gear.—Certain kinds of work must be located in a fixed relation to each other when they are installed in the mechanism of which they form a part. It is therefore a decided advantage to take this into consideration when designing tools for these parts. An example of this kind is given in Fig. 218, the work *A* and *B* consisting of two automobile timing gears. A definite relation must be kept between the keyways which are to be broached and the teeth which have been previously cut. In addition to this each gear must be properly marked in a particular place so that when the two gears are assembled in the car the gears can be meshed at these points, thus assuring the correct position of the cams on the camshaft in relation to the throws of the crankshaft.

The work is located on two studs, the locating pins at *C* and *D* being provided to determine the relation of the keyway with a given tooth. The method used is apparent from the illustration. The marking of the teeth is done by the swinging arms *H*, each of these having in it a pointed pin *K* which, when struck with a hammer, makes a mark on the gear. After the marking

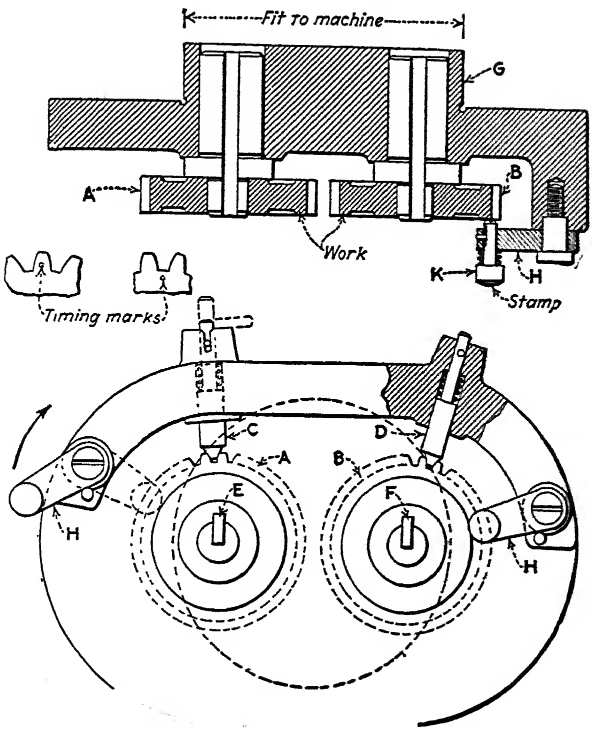


Fig. 218. Broaching Fixture for Timing Gears

has been done the arms are swung out of the way so that the gears can be readily removed. The principles illustrated here can be applied in other cases where the location of the keyway must be kept in relation to some other part.

Examples of Index Broaching.—Index broaching is of various kinds and the requirements are also varied. In one case accuracy may not be of the greatest importance, while another may require the greatest care to produce it within the necessary

limits. These points must be considered when designing fixtures for any kind of an operation. So far as the fixtures are concerned the indexing devices which have been described in previous articles cover the situation quite thoroughly, so there is no necessity for repetition. Several examples of work which may require an indexing device of some kind are shown in Fig. 219. The work *A*, for example, is of such large diameter that

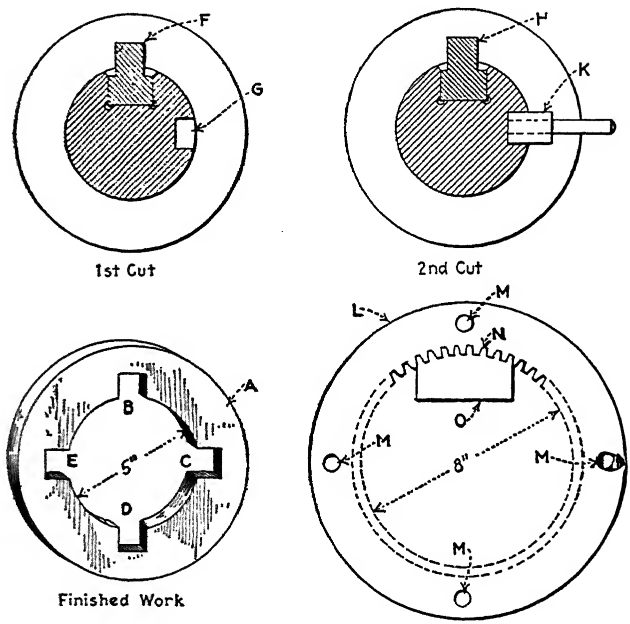


Fig. 219. Examples of Index Broaching

it would hardly be desirable to make up a four spline broach, both on account of its weight and also the expense. It is evident therefore that an indexing device would be of assistance in a case of this kind. A method is illustrated in order to point out the errors into which a tool designer may fall unless he analyzes a situation carefully. Let us assume that the work is set up on a guide bushing so that a broach can be used as at *F*. If then the guide bushing has a slot *G* located at 90 deg. from the one which is used as a guide for the broach, it would appear that the work could be turned around on the bushing to take another position and located with a plug as at *K*. With this

plug in place a broach cut could be made as at *H*, and the operation could be repeated to finish the other keyways. If the work *A* is to be machined at *B*, *C*, *D* and *E* it is apparent that any slight error in location of the plug *K* would cause an error which would become more and more as the work is turned around, so that the piece when completed might be valueless. Hence, it is seen that a method of this sort is not good practice and will not produce accurate work.

An index fixture of simple design could be used with much more satisfactory results, and although it might be a little more expensive than the method illustrated, the product obtained

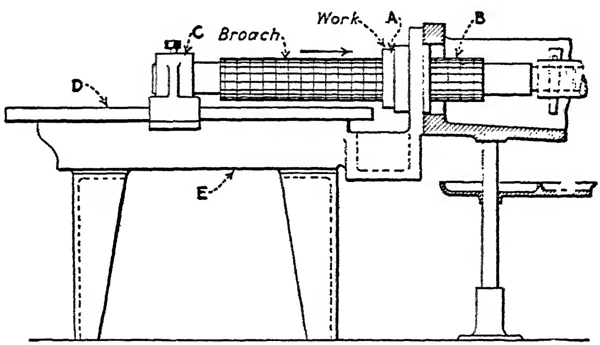


Fig. 220. Outboard Support for Heavy Broaching

would pass inspection. Another example of work which requires indexing is shown at *L*, which is an internal gear of large diameter. The work is to be done by the broach *N* which is so designed that it will cut a number of teeth at one time. The work can be located on pins in the holes *M* on a simple index plate so that the successive broaching operations will produce a finished gear. Any good method of indexing can be applied to a piece of work like this, although it is essential to use a method which will not multiply the error as in the instance just mentioned. An indexing fixture should be made up with the indexing bushings or slots as far away from the center as possible in order to insure accurate work.

When the use of a heavy broach is necessary the weight of the overhanging portion of the broach is likely to be a matter of serious moment. It is evident that if it is to be supported

at all it must be done by some arrangement which will permit it to be aligned properly, or else the work produced may be inaccurate. When one hole is to be broached in accurate relation to another accurate alignment is also necessary, so that in each of these two cases it is well to use the outboard support.

An example which shows the application of this device is illustrated in Fig. 220, the work *A* being similar to the internal gear shown in the preceding illustration. In this case, how-

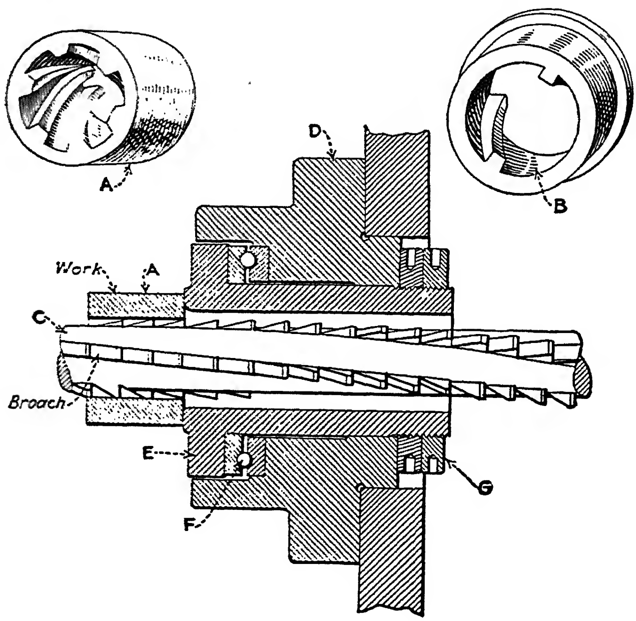


Fig. 221. Method of Spiral Broaching

ever, the broach is so made that all of the teeth are cut at the same time, and as a consequence the broach is both large and heavy. The support *E* is provided with a slide *D* on which is mounted the member *C* which holds one end of the broach as indicated. Provision is made so that proper alignment can be obtained without difficulty.

Spiral Broaching.—When it is necessary to broach a spiral, two methods are possible; the broach may be arranged so that it will revolve while cutting, or the work may revolve while the broach is passing through it. In Fig. 221 two examples of

spiral work are shown at *A* and *B* and one method of broaching is shown. The work *A* is mounted on the broach *C* so that the pulling action comes against the face of the bushing *E*. This bushing is adjusted by the two check nuts at *G* so that it will revolve freely and all of the thrust is taken on the thrust bearing *F*. The fixture *D* is mounted on the faceplate of the machine and fastened by means of screws.

In operation the angularity of the broach teeth causes the work to revolve so that the spiral is cut without other assistance.

CHAPTER XI

DESIGN OF RIVETING FIXTURES

Riveting Machines—Types of Rivets—Locating and Clamping—Use of Tables—Ring-Staking Tools and Fixtures—Ejectors.

The process of riveting is used extensively in many classes of work, both small and large. For example, adding machines, typewriters, cash registers, etc., have many small parts made up from two or more units, assembled and riveted together to make a single component of the mechanism. Automobile frames, steel girders for buildings, ship plates, bridges and many other forms of structural work depend largely on the process of riveting to locate and hold together the various structural members. Rivets in structural work are usually heated before driving but for small parts cold rivets are used and it is here that riveting fixtures are used to advantage.

Methods of Riveting.—Rivets are headed over either by hand or machine. In some cases the rivets are in such a position that it is very difficult to head them over on a machine, necessitating a hand operation. Hand riveting as a rule does not require a fixture.

The machines used for riveting are of two general types, one of which heads the rivet by spinning the metal over to form a head; the other peins the metal by striking successive blows. Both types are extensively used, the selection being dependent upon the kind of work that is to be done.

Riveting machines are made in several styles, both horizontal and vertical; single, double and multiple spindle; operated mechanically or by pneumatic power. In some machines work is placed on an anvil and the spindle is moved up to it; in others the anvil itself moves toward the spindle. In the reciprocating type of machine the spindle is arranged to hold a pein of suitable form, while in the rivet spinning machine hardened rolls

are used. In either machine the action is very rapid and work is produced much more quickly than by hand riveting.

Machine riveting produces sharp, quick blows which are rendered elastic by springs or rubber cushions. In the pneumatic type the air acts as a cushion. The force of the blow can be regulated by the operator. The application of riveting fixtures covers such a wide field that it will be understood better by referring to the various examples given in this article. The facility with which work can be handled generally governs the production, as the actual time consumed by the riveting operation is very small.

The kind of work to be riveted affects the shape and form of

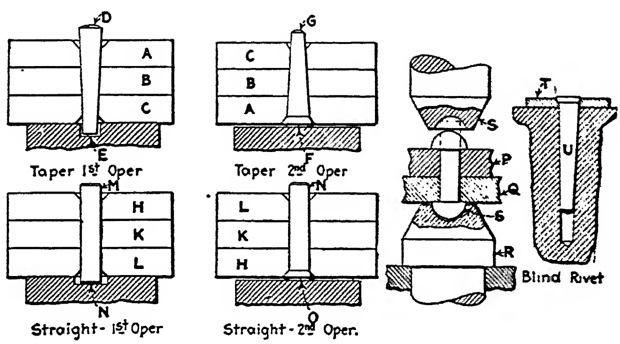


Fig. 222. Types of Rivets and Riveting

rivets used. Straight rivets with round heads are often used when the appearance is important and when there is plenty of room in the mechanism so that projecting rivet heads will not interfere with some other part. Straight rivets with flat or countersunk heads are also much used for plain work. Taper rivets are valuable when correct relation of several parts to each other is required.

Fig. 222 shows several types of rivets and methods of riveting. Pieces *A*, *B* and *C* are to be riveted together with taper rivets as shown at *D*. Before the riveting operation the parts are reamed in a locating jig and rivets are inserted to act as dowels and keep the parts together. The form of locating jig mentioned has been described under the head of drill jig design.

In riveting these parts together a taper rivet *D* is used. The

first operation heads over the large end of the rivet and it is important that clearance should be provided in the riveting fixture at E so that the rivet will not bottom. After the large end has been headed the work is turned over so that the small end comes uppermost as at G. The other head of the rivet rests on the anvil at F. Care must be taken to see that work does not rest on the block in this case as the rivet head might be somewhat lower than the surface of the work which would allow it to be forced out during the riveting process. This would cause a loose fitting rivet and inaccurate work. It is important that taper rivets should be made of uniform length and the holes must always be carefully reamed.

Straight Riveting.—When straight rivets are used in fastening several pieces together as shown at H, K and L, the anvil used must be cut away to allow the end of the rivet to seat itself as shown at N. The depth of the recess should be sufficient to allow for a head on this end of the rivet when the work is turned over. After the head M has been formed the work is reversed and the head takes the position O. The other end N can then be riveted taking care that the head O rests firmly on the anvil.

Round Head Rivets.—This is the most common type of riveting, as the rivet is always provided with one head. This head rests in a special anvil R which is cupped at S deeper than the rivet head and slightly smaller in diameter. This supports the rivet and also prevents it from turning. Riveting of this kind is often done on a punch press as well as a riveting machine and several rivets may be headed at the same time, providing the work is uniform.

Blind Rivets.—When rivets do not go through the piece of work they are called blind rivets and are generally made in taper form as shown at U. When a case of this kind is found, the taper of the hole should be slightly different from that of the rivet in order that a wedging action will be produced due to the difference between the two tapers. This wedging action is sufficient to hold the rivet in place.

Method of Riveting Rollers.—If a roller such as that shown at C in Fig. 223 is to be held in place in a piece of work A by means of the special rivet B, provision must be made so that the roller will be free to move on the rivet. Suitable allowance

must be made so that the shoulder E is slightly longer than the roller. When the rivet is headed on the upper end there will be sufficient clearance to allow the rolls to revolve. In setting up work of this kind a special anvil can be made as at D. This anvil is smaller than the rivet head in order to prevent upsetting the head. The bushing E serves to locate the rivet and roll.

The method of riveting a hinge is shown at F and G. The anvil K is made so that it will hold the round head rivet H.

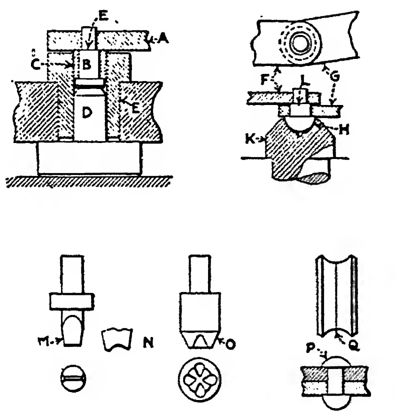


Fig. 223. Forms of Riveting Tools

A shoulder is provided at L which gives the proper allowance between the two parts. The operation of riveting can be done in the regular way.

Several forms of peins are shown at M, N, O and Q. The form M is used for flat and countersunk rivets. N is somewhat similar but being cupped slightly has a greater spreading action on the rivet. The form O has a series of points which tend to pein the rivet rapidly. In the rivet spinning machine a hardened roll Q is used to form a rivet head as indicated at P. There are many other forms of peins used in riveting, the shape of these depending on the work to be done and somewhat upon the material of which the rivet is composed.

General Notes on Design.—Rivets often act as dowels in locating several parts with relation to each other when great accuracy is not important. The design of fixtures for this class

of work is not at all difficult. Work having a center hole and in which rivets are located radially should be provided with a location hole unless the shape of the piece is such that it can be easily set up in the desired position. For instance, if two washers are to be riveted together so that the center holes will be in alignment, a stud can be used as a locater; whereas if the outside diameters are to be in alignment the work should be nested and located from the outside. In riveting two gears together so that the teeth will bear a certain relation to each other, pins or pawls should be used between the teeth.

The location points for work that is to be riveted should be as near to the outside as possible, in order to obtain maximum accuracy. Clamps are not always required in riveting work together but they are frequently used in order to prevent spreading of the work when the pressure of the hammer is applied. A rivet spread out between two pieces of work is the ordinary result unless clamps are used, the vibration of the machine causing the two pieces to separate. Various types of rivets require special forms of anvils in order to avoid the possibility of bad rivets. Several points in this connection have been brought out in Figs. 222 and 223.

The position and location of the fixture on the riveting table must be so arranged that the rivet will be directly over the anvil and in contact with it. The production required on any riveting proposition does not necessarily affect the design of the fixture as there are not many ways of riveting work. Positive and rapid clamping are important. however, and the accuracy of the product is dependent upon the location and the use of proper rivets.

Vibration should always be considered. All loose parts of fixtures should be well screwed down so that the excessive vibration cannot loosen them and cause trouble.

Riveting Several Pieces Together.—In Fig. 224 is illustrated a method for locating and clamping several pieces together for riveting. This is an example which makes plain the importance of proper locating and clamping, in order to prevent trouble due to vibration and also to insure accuracy. Unless the work is held properly it is likely to open up and separate so that the rivet may bulge out as shown at *C* between the plates *A* and *B*. Rivets should not be used as

dowels to locate work if great accuracy is required; other means should be provided. In the example shown the four pieces *D, E, F* and *G* are slipped over the center stud *H* and clamped by means of the nut shown. The locating plug *K* is a loose piece which is pushed through all the pieces and into the bushing *L* which locates it. This is better than a station locating stud similar to the center one, because it is less likely to be sprung out of its true position. The locating plate is slotted in three places to allow for the rivets *N*. For riveting the other side of the work another fixture is necessary.

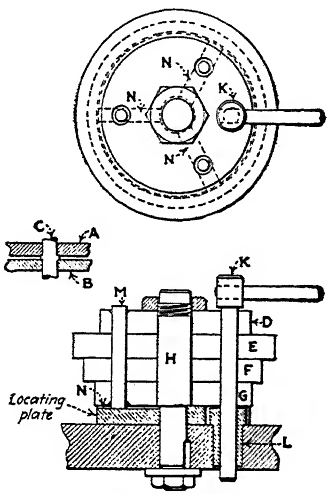


Fig. 224. Locating and Clamping for Riveting

Method of Locating and Clamping.—The type of fixture shown in Fig. 225 is very good for a number of kinds of work and it can easily be standardized. In the example given, the work *A* is to be furnished with a pin B which is to be riveted in place. The center distance from *C* to *B* is very important. The work is located on the stud *C* and the riveting is done over the anvil shown. The anvil is directly over the portion *H* which fits the riveting machine. The work is nested between the fixed member *E* and the movable pin *F*, the latter being arranged so that it does not turn as it is moved by the screw. This clamping arrangement has been previously described.

Attention is called to the location of the pin *C* in the bush-

ing *D*. This provides for easy replacement of the pin when worn and thus preserves the accuracy. Clearance should be allowed at *G* so that the work will not rest on anything except the rivet.

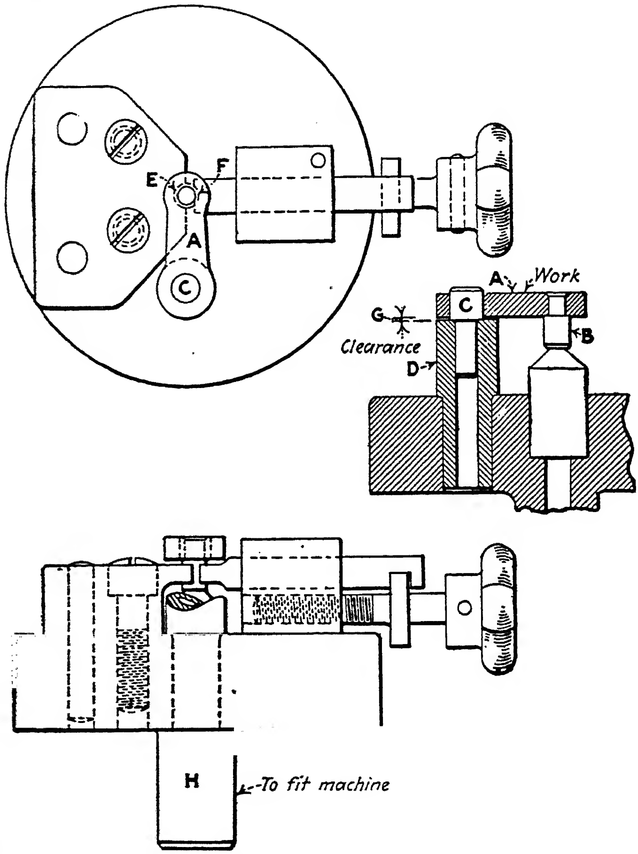


Fig. 225. Riveting Fixture Showing Methods of Locating and Clamping

Swinging Type of Riveting Fixture.—To assist in the rapid handling of work a swinging fixture is often an advantage. An example of this kind is shown in Fig. 226. The work *A* has two rivet studs as indicated at *D*, these being located at *B* and *C* as indicated. As they operate in a face cam in the completed mechanism their location is important and they must be firmly riveted into position. The work locates on a central stud *E* and

is held firmly in position by the pawl F operated by the thumb-screw G. The swinging member of the fixture is pivoted at H so that in operation the rivets can be brought into position under the hammer by swinging the lever M until it strikes the pins at K and L. When in the riveting position ample support

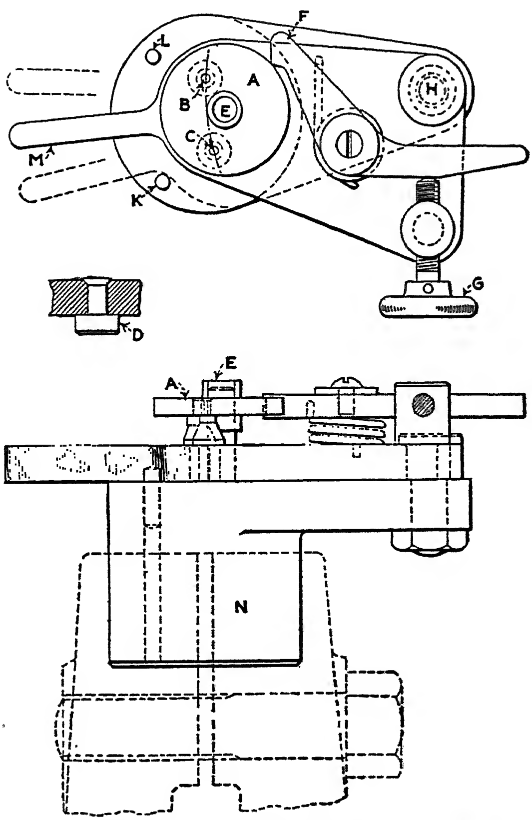


Fig. 226. Swinging Type Riveting Fixture for Two Holes

is given by the fixture at N, this portion being clamped in place in the riveting machine. The dotted lines indicate the two positions of the fixture when riveting. This is a clean cut example of a simple riveting fixture involving principles which can be applied to other work of similar character. Tables are often used on riveting machines in order to simplify the location of fixtures which are to be used for several operations. Also when

fixtures are large and when rivets are so spaced that they cannot easily be located on an anvil, a table permits easy location and makes the operation of riveting more convenient. A few points in connection with the use of tables are illustrated in Fig. 227. It is important that the table should be so located that the stem *A* will be in positive contact with the anvil on the machine. There must never be a space between them as indicated at *B* as this would not give proper support. The

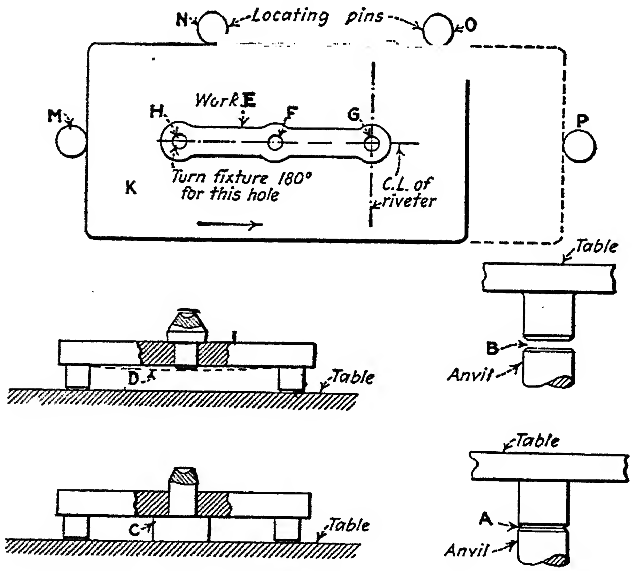


Fig. 227. Use of Special Table with Locating Pins

fixture which may have an anvil of its own, must also always be made so that the under side of the anvil is in contact as at *C*. It should never be made as shown at *D* as this would not give good results and would buckle as indicated by the dotted line.

In locating any fixture on the table an arrangement of pins can be provided so that several locations can be easily made. If a number of pieces of a similar kind are to be riveted it is often possible to standardize the tables and the relation of the pins so that fixtures can be built which will all be usable on the same table. The work *E* for example is to be riveted at *F*, *G*

and *H* and it is located for the operation on the riveting fixture *K*. Locating pins are provided at *M*, *N*, *O* and *P* so that by moving the fixture along as indicated by the dotted lines, all three rivets can be brought into position over the center line of the riveting machine. Other fixtures for work of similar shape and size can be so made that the same table can be used in each case.

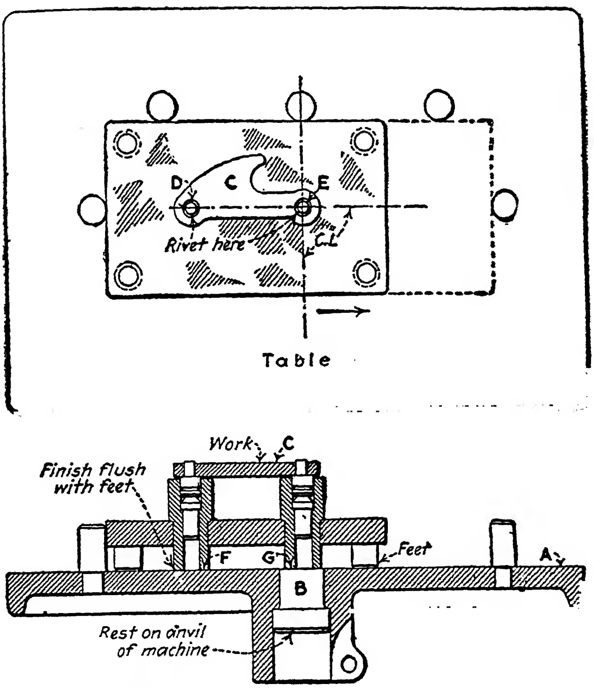


Fig. 228. Example of Riveting Fixture Using Special Table

In Fig. 228 is shown another example of a fixture used on a special table *A*. The plug *B* must rest on the anvil of the riveting machine. The work *C* is to have the two pins *D* and *E* riveted in place and the method of location here is the same as that previously described. The ends of the bushings at *F* and *G* must be ground so that they are flush with the feet of the fixture in order that they will be in contact with the plug *B* during the riveting operation. The locating pins on this table are arranged in similar fashion to those previously described.

Riveting Fixture Used for Both Sides of Work.—The designing department can often help in simplifying the design of riveting fixtures by paying attention to the location of rivet holes, and placing them in such positions that the same fixture can be used for riveting both sides of the work. An example which illustrates the advantages of this forethought is shown

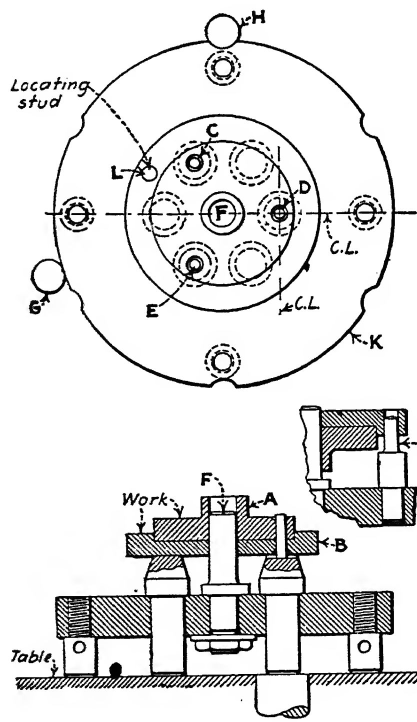


Fig. 229. Riveting Fixture for Both Sides

in Fig. 229. The pieces *A* and *B* are riveted together at three points *C*, *D* and *E*, these points being 120 deg. apart and the same distance from the center. The pieces are assembled on the center plug at *F*, resting on six plugs as indicated. Three of these plugs are cut away to allow for the heads of the rivets, while the other three are plain on the top. For the first riveting operation the slotted pins are used successively; but for the second the plain pins are used, the work being turned over.

Two pins *G* and *H* are used in the riveting machine table to

act as locaters for the fixture. It will be noted that the edge of the fixture is notched in several positions so as to give correct locations for the various rivets. The notch acts as one locater against the pin *H*, while the other location is fixed by a contact

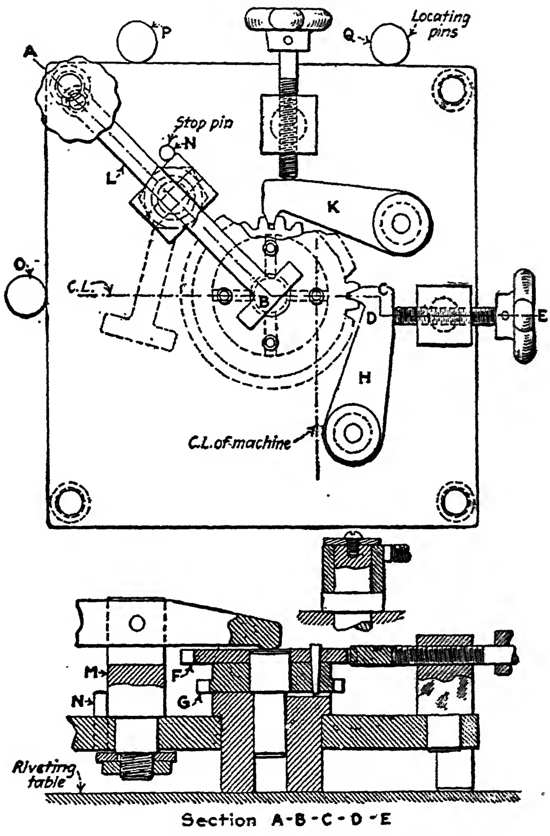


Fig. 230. Riveting Fixture for Two Spur Gears

of the outside of the fixture with the pin *G*. A pin *L* is placed in the fixture to locate the two pieces and attention is called to the manner in which it is cut away so that it will not interfere with the flange indicated. All of the six studs used for riveting are flush with the legs of the fixture thus assuring proper support when they are brought into position for riveting. This fixture is built high in order to make it easier to turn over; it is

dirt proof and easy to clean. The design being so made that both operations can be done in the same fixture cheapens the cost considerably and also expedites the operation.

Riveting Fixture for Two Spur Gears.—When gears are to be riveted it is often necessary to locate each of them by the teeth in order to preserve the correct relation. Riveting fixtures for this class of work should be carefully designed in order to make sure that no inaccuracies will result from imperfect location. An example of this kind is given in the two pieces *F* and *G*

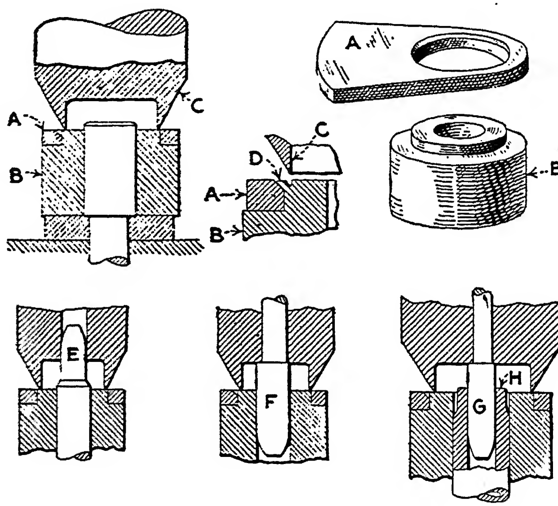


Fig. 231. Example of Ring-Staking and Types of Ring-Staking Tools

in Fig. 230, in which there are four rivets to be driven as indicated. The rivets used are tapered, therefore provision must be made to prevent the small end of the rivet from bottoming in the slot during the first riveting operation. The work is located on a central stud and the pawl *H* engages with a tooth in the part *F;* the pawl *K* is used similarly with the gear *G.*

A swinging clamp of special design is used to hold the work as indicated at *L.* This clamp swings on a stud *M* into the position shown by the dotted line so that the work can be easily removed. The stop pin *N* limits the movement. The riveting table has three pins *O, P* and *Q,* which serve to locate the riveting fixture in the manner previously described. For certain classes of work fixtures of this kind are very much used and by

using a standard plate a number of fixtures can be handled on the same table without difficulty.

Ring Staking Operations.—Ring staking is the process of peining over or swaging two pieces of work together by means of a circular tool having a sharp edge which swages or forces the metal on one piece of work over into a countersunk portion on the other. A ring staking operation is often used when work is to be riveted, as it prevents the parts from coming apart or

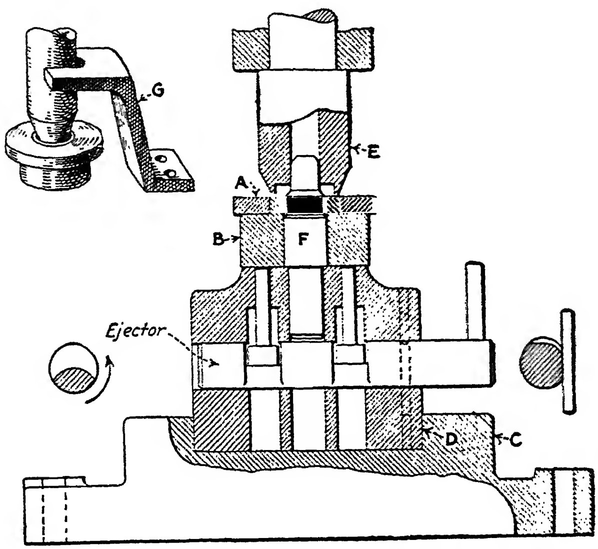


Fig. 232. Ring-Staking Fixture with Ejector

separating, the rivets serving to keep the pieces from turning in relation to each other. The machine used for ring staking is a punch press.

Fig. 231 shows a few examples of work requiring ring staking, and the tools used for the operation. The cam *A* and the bushing *B* are to be fastened together by staking with the tool *C*. The enlarged sectional view shows at *D* the effect of the staking operation, the metal being upset and forced over into the countersunk portion. Ring staking tools are frequently piloted to assist in preserving accuracy. In the example *E* the locating stud in the fixture is carried up far enough to act as a pilot in the staking tool. The pilot *F* is in the staking tool itself so that

it centers the work as it enters the hole. In another example the pilot *G* in the staking tool enters a bushing on which the work locates, the bushing being relieved slightly at *H* so that if the metal is contracted by the staking tool it can still be removed from the bushing without difficulty.

Ring Staking Fixture with Ejectors.—Fig. 232 shows a complete fixture for ring staking the two parts *A* and *B*. The fixture fits in a shoe *C* on the bed of the punch press, being located and held in place in some approved manner. The counterbored portion of the shoe *D* can be standardized so that a number of fixtures can be used with the same shoe. The staking tool *E* fits the ram of the punch press as indicated. The work locates on a stud *F* which extends above it and acts as a pilot for the tool.

Work of this kind sometimes clings to the tool and rises with it, in which case a stripper like that shown at *G* may be found an advantage. Work may also stick on the locating plug so that it is not easily removed without using an ejector. It is advisable to provide for both contingencies by using both stripper and ejector. The form of ejector used in this instance has been previously described so that further comment is unnecessary. It is important to know the stroke of the press when designing ring staking fixtures, in order that the height of the fixtures may be kept within the required limits.

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